# THE

# SCIENTIFIC MONTHLY

Cover: Smelting Four Centuries Ago
[*Courtesy Herbert C. Hoover and Library of Congress, see page 254*]

# ❧ Science and Technology ❧

## Brake Control

An automatic control that meters power to the brakes when foot pressure on the accelerator is relaxed is designed to reduce the distances required for stopping cars and trucks. The key part of the system is a vacuum-powered control valve that is mounted on the engine. The valve operates in conjunction with both the accelerator and the brakes, and eliminates the need for a brake pedal. When the unit is installed, 1 in. is added to accelerator travel, which is divided into three zones: ¾ in. for the braking zone, ¼ in. for the neutral or coasting zone, and the remainder for acceleration. According to the National Safety Council, an automobile traveling at a speed of 30 mi/hr requires 84 ft for stopping. It is reported that the new system reduces the stopping distance for this speed to 38 ft. The system will not lock the wheels when the brakes are applied while the car is moving on dry pavement. Installation requires about 1 hr. (Hemphill, Inc., Automatic Brake Div., Dept. SM, Box 331, Gowanda, N.Y.)

## Draftless Air Conditioning

Modular Multi-Vent air diffuser has been designed to provide draftless air conditioning and uniform temperature control in locations where a high number of air changes is desired. Air is introduced vertically at low velocity through a perforated ceiling panel into a room or working area. It is reported that the system, which can be concealed from view, is suited to ceilings that have received acoustical treatment and fire proofing. The system can also be used with heating and ventilating systems. (Pyle-National Co., Dept. M-V, SM, 1334 N. Koster Ave., Chicago 51, Ill.)

## Tube Tester

Fil-A-Test, a new device for testing the filaments of television tubes in the home, is now available. The unit contains a pilot bulb that lights when an electron tube with a good filament is placed in one of the three standard sockets that are mounted on the assembly. The necessary power is supplied by standard flashlight batteries. (Bava Co., Dept. F-109, SM, 3655 E. Canfield St., Detroit 7, Mich.)
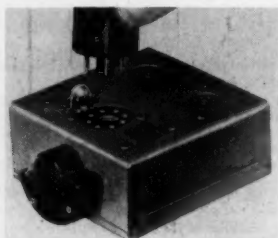


## Folding Machine

Designed to eliminate hand-folding operations in offices, the new Premier Auto-Fold can produce any of the seven most-used business folds at a rate of 7000 pieces per hour. The machine, which is comparable in size to a standard typewriter, is portable. Statements, reports, or regular correspondence utilizing paper stock up to 9½ by 14 in. in size can be handled by the machine. The unit is available in either electric- or hand-operated models. (Martin-Yale, Inc., Dept. SM, 314 Bell Ave., Chicago, Ill.)

## Punched Tape Control System

Binotrol is a new punched-tape control system for the automatic operation of machine tools and industrial equipment. The system operates on a digital-to-analog principle; its circuitry is composed mainly of telephone-type relays that transmit instruction signals from a plastic tape. A step-by-step program for a particular machine can be arranged by a process engineer, punched into the required tape with the aid of a code book, and then run off immediately or stored for future use. Each movement is controlled through 32 hole positions so that a machine will start, stop, or recycle automatically. The control console is approximately the size of an office desk. (Barnes Engineering Company, Dept. SM, Stamford, Conn.)

## Miniature Hearing Aid

A new miniature, one-unit, 3-transistor hearing aid that can be worn entirely within the ear is self-contained and cordless. It permtis the wearer to hear at normal ear level and simplifies the use of the telephone. It is reported that the instrument is not subject to the distortions present in models that use a separate transmitter. The new hearing aid is made possible by the use of three microscopic transitors and a miniature power cell. It weighs less than ½ oz. (Dahlberg Co., Dept. SM, Golden Valley, Minneapolis, Minn.)

## Nuclear Instrument Catalog

A new 48-page catalog describing radiation measuring equipment, radiochemicals, and accessories for medical, industrial, and research applications has been released by the Nuclear Instrument and Chemical Corp. Photographs and descriptions of scalers, count rate meters, portable instruments, and proportional and scintillation counters, as well as a radiochemical price list, are included. Catalog P. (Nuclear Instrument and Chemical Corp., Dept. SM, 229 W. Erie St., Chicago 10, Ill.)

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# Pan-Indian Culture of Oklahoma

JAMES H. HOWARD

*Mr. Howard has recently joined the staff of the Kansas City Museum, Kansas City, Missouri. He did his undergraduate work at the University of Nebraska and is now completing his doctorate at the University of Michigan. In 1951–52 Mr. Howard directed archeological work at the Like-a-Fishhook Village site (Old Fort Berthold) in the Garrison Reservoir area of North Dakota. He has also done ethnographic work among the Ponca, Dakota, and Plains-Ojibwa tribes.*

DURING the 19th century many Indian tribes from the Southeastern, Northeastern, and Plains areas were settled in various parts of the territory now included in the present state of Oklahoma. With the collapse of the old tribal life prior to and immediately subsequent to their placement on reservations in Indian Territory, a stage of acculturation was reached which seemed to presage complete assimilation. Technologically, economically, in social organization and religion the various Indian tribes seemed to be rapidly approximating white culture.

This was, however, more apparent than real, for, rather than becoming nondistinctive members of the dominant culture, many Indians have instead become members of a supertribal culture, which we here term *pan-Indian*. By *pan-Indianism* is meant the process by which sociocultural entities such as the Seneca, Delaware, Creek, Yuchi, Ponca, and Comanche are losing their tribal distinctiveness and in its place are developing a nontribal "Indian" culture. Some of the elements in this culture are modifications of old tribal customs. Others seem to be innovations peculiar to pan-Indianism.

There do not seem to be any accounts of pan-Indianism in the literature, although Petrullo (1) touches upon the subject in his study of Delaware peyotism:

The reservation system has caused the old tribal animosities to disappear, and there has arisen a sympathetic attitude of the various tribal units toward each other, with the result that intercourse between them has become common, and each other's rites are observed and studied with the avowed purpose of comparison. This constant interchanging of ideas is giving rise to a novel feeling for Indian nationality. As welcome as this may be to one interested in the progress and development of the Indian, it must not be underestimated as being of prime importance in the disintegration of tribal culture patterns. The Delawares are actively participating in this, and as a result not only have they assimilated many of the ideas emanating from other tribes, but have disseminated their own widely.

The late Karl Schmitt, of the University of Oklahoma, read a paper entitled "A possible development of a pan-Indian culture in Oklahoma" at the 1948 meetings of the Central States Branch of the American Anthropological Association. He intended to publish this paper, but his untimely death halted the project. William Newcomb, Jr.,
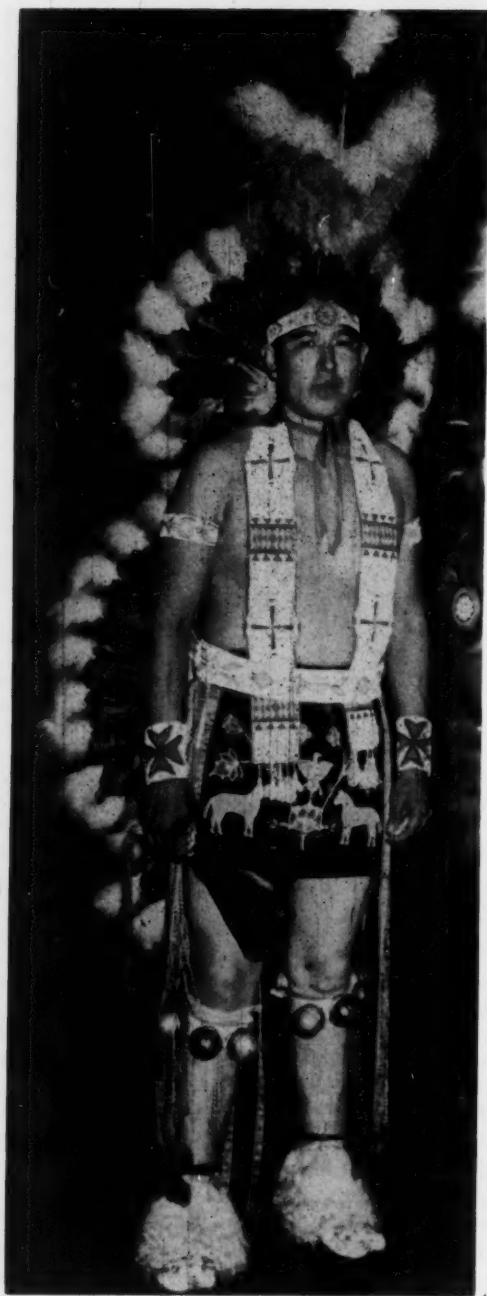
Fig. 1. Ponca Indian dancer wearing the "feather" costume.

in his unpublished doctoral dissertation *The Culture and Acculturation of the Delaware Indians* (2), presents an interesting treatment of Delaware participation in pan-Indianism.

While conducting ethnological studies among the Southern Ponca in the summers of 1952 and 1954, I was able to observe various aspects of this interesting cultural phenomenon and to discuss it with both young and old Indian informants. The purposes of this article are to describe some of the more striking features of Oklahoma pan-Indianism as it exists at the present time and to isolate what appear to be some of the principal contributing factors. Most of the data were secured by me, either from personal observation or from informants. I have drawn, however, both from Newcomb's dissertation (2) and unpublished notes of Karl Schmitt, which he permitted me to read in 1951.

It is not known whether all of the tribes now resident in Oklahoma participate in pan-Indianism. At least some members of the following tribal groups, however, are involved: Southern Ponca, Osage, Kansa, Quapaw, Southern Iowa, Oto, Missouri, Southern Cheyenne, Southern Arapaho, Pawnee, Wichita (3), Caddo (3), Tonkawa, Kiowa-Apache, Kiowa, Comanche, Southern Sauk, Oklahoma Kickapoo, Caney Creek and Anadarko Delaware, Eastern Shawnee, Oklahoma Seneca, Oklahoma Wyandot, Western Cherokee, Western Creek, Western Seminole, and Yuchi.

Pan-Indianism is not spread evenly among the tribes that participate in this phenomenon. Participation among the Cherokee, Creek, Seminole, and Yuchi is as yet minimal. Among the Central Algonquin it seems to be an added "overlay" to the native culture. In some of the small tribes, such as the Kansa and Quapaw, it is "the" Indian culture. Among some tribes pan-Indianism is seen as "foreign," and there is a conflict between it and the older native culture. In other groups it is seen as more compatible. It is by no means a simple phenomenon.

## Characteristic Features

*War dance.* In my study of the Dakota grass dance I commented on the function of this ceremony as a rallying point for conservative Dakota (4). The Oklahoma version of this dance, together with minor attendant dances and activities, serves a similar purpose. In fact it might well be termed the prime secular focus of pan-Indianism. It is commonly called the "war dance" by both Indians and whites in Oklahoma.

The dance is said to have originated with the Pawnee and spread from them to most of the Plains tribes (5). Although it was originally a men's war society, with religious overtones, it has now become, in all tribes except the Osage, more of a social affair. It consists, essentially, of solo dances performed *en masse*, accompanied by a group of singers at a large drum. Since it requires no special rehearsals, it is ideally suited to the mixed groups that assemble at pan-Indian celebrations.

Powwows centering around this dance are commonly sponsored by the tribal councils of various Oklahoma Indian groups, or, more recently, by intertribal Indian clubs. In either case dancers are drawn from many tribes, and even Northeastern groups, such as the Delaware and Seneca, and Southeastern groups, such as the Cherokee and Creek, which did not possess the dance in their original homelands, now furnish performers for the functions of the Pawnee, Comanche, and other Plains tribes.

In this connection it is interesting to note that in the old Plains grass dance the line of direction was clockwise (6) but in the pan-Indian war dance of the present day it is the reverse. This may reflect the influence of the stomp dance and other Eastern dances, which move in a counterclockwise direction. Those Plains tribes resident outside Oklahoma, such as the Omaha of Nebraska and the Dakota of North and South Dakota, still retain the original clockwise progression. Older Pawnee and Southern Ponca interviewed in 1954 admitted that the counterclockwise circling was an innovation of the younger generation.

*Costume.* The costumes worn by male dancers in the pan-Indian war dance are likewise distinctive and depart considerably from the older Plains styles upon which they are based. Figure 1 shows the most common style, the "feather," or "fancy-dancer," outfit. This combination is favored by most of the younger and more active dancers.

A spectacular feather roach is the standard headpiece. This is a pan-Indian development of the porcupine and deer hair roach of the Plains and Eastern Woodlands areas. It was probably devised as a substitute for the hair roach originally, since Oklahoma is far south of the porcupine region and deer have been scarce in this state for some time. It has now become, however, *de rigueur* for pan-Indian dancers, and is worn in preference to the older style by many. In 1950 I saw a Southern Ponca dancer, who I knew had just purchased two fine porcupine and deer hair roaches while visiting the Teton-Dakota, wearing a feather roach instead.

On the back at the level of the shoulders and at the hips, the pan-Indian "feather" dancer wears a "shoulder bustle" and a "back bustle." Both of these ornaments are modern versions of old Plains ornaments, the latter being a streamlined version of the old "crow belt," a warrior's insignia (7). Some dancers also wear arm bustles, which are apparently a pan-Indian development with no direct antecedent. Usually the feather roach, shoulder bustle, arm bustles, and back bustle are all made of matching feathers and downy plumes, often in pastel shades.

A "choker" neckband, beaded chest ornament (a development of the old Plains otterskin necklace), armbands, gauntlets, a wide beaded belt, breechcloth, swimming trunks, kneebells, angora anklets, and moccasins complete the "feather" costume. Usually the moccasins are of the hard-soled Plains type, even though the wearer may belong to an Eastern tribe that traditionally uses soft-soled footgear.

The feather costume has become quite standardized throughout the pan-Indian area and has virtually replaced the older and more distinctive costume styles. Only rarely can one distinguish a Shawnee, say, from a Comanche on the basis of some piece of heirloom beadwork.

This standardization of costume has not yet occurred in the case of feminine attire. This does not imply that participation in the pan-Indian war dance is limited to males, however. In 1954 I observed women and girls in fine old Shawnee, Delaware, and Creek costumes circling the drum at the annual Pawnee powwow. One development, nevertheless, has taken place and may presage further standardization. This is the evolution of the "princess crown" type of headband (Fig. 2) from the older plain form. This undoubtedly occurred as a result of the powwow "princess" contests that are held in conjunction with most celebrations. The "princess crown" seems to be a strictly pan-Indian development, and it is worn with various tribal costumes. Although it is usually worn with a single black-and-white golden eagle tail feather in the back, the "princess" of a powwow is allowed to wear a downy eagle plume (an old Plains indication of sacredness or high rank) instead for the duration of her "reign."

Some Indian girls, apparently resenting the relatively restricted role that tradition and the heavy buckskin dress has assigned them in the dance, have now taken up the male style of dancing, wearing a slightly modified version of the man's "feather" costume. This too seems to be a pan-Indian development, although it shows signs of spreading. In 1949 an Omaha girl attempted to introduce this innovation at her home powwow in Macy, Nebraska. Although she attracted a small following of other girls almost immediately, traditionalists of the tribe forbade her further participation.

In connection with the war dance, certain other dances are commonly presented at pan-Indian powwows for the sake of variety. These include the snake dance, round dance (the old Plains scalp

dance in slightly modified form), buffalo dance, forty-nine dance, and eagle dance. All but the last are performed in the same costumes used in the war dance. The eagle dance is performed by specially rehearsed groups, the dancers wearing Pueblo-inspired eagle costumes, with beaked eagle headdresses and winglike sleeves.

*Stomp dance.* Another dance, now a common feature at pan-Indian gatherings, seems to deserve special attention. This is the stomp dance, formerly performed at religious ceremonies by Eastern tribes. Like the grass dance of the Plains, however, it has now become more of a social performance. Since it requires no particular costume, it is usually performed after the war dance section of the program at a pan-Indian celebration and may continue throughout the night. Its features are antiphonal singing by a leader and a file of dancers to the rhythmic accompaniment of shell or condensed-milk-can leg rattles that are worn by a "shell-shaker" girl who follows immediately after the leader.

Although the best stomp dance leaders are usually members of Eastern tribes, such as the Cherokee or Creek, at least one Comanche and several Pawnee and Ponca can sing for the dance. It is a regular feature of the annual Ponca, Pawnee, Oto, and Comanche powwows. Since the pan-Indian blending is not yet complete, a powwow in the area of the Plains tribes is likely to feature Plains type dances rather than the stomp dance, whereas the reverse is more likely to be true at a celebration in the Creek or Seminole country. Nevertheless *both do occur* at the same gathering, and powwow promoters are anxious to offer both to those in attendance.

*Indian store.* One of the most interesting developments of Oklahoma pan-Indianism is the "Indian store." Such an establishment may be found in most of the larger cities and towns of Oklahoma. Particularly well known is one in Pawnee, Oklahoma, which conducts a flourishing mail-order business and furnishes dancing costumes, not only to local tribes, but to such distant groups as the Blackfoot in Montana and the Ojibwa of Minnesota. The firm employs several Indians on a full-time basis to manufacture costumes of the "feather" type just described.

It is possible for a would-be Indian dancer to purchase a complete costume at such a store, and many do just this. In 1954 the manager of the store in Pawnee informed me that he had sold out his entire stock of costumes during the week of the annual Pawnee powwow the previous year. The costumes offered in this store are not the "junky" imitations offered by firms that cater to Scout

groups and the theater but are well-made, though standarized, outfits that take account of recognized pan-Indian canons of style and workmanship. Some of the Indian stores also carry stomp dance equipment, such as the leg rattles worn by the shell-shaker girl. A few even handle peyote equipment and regalia, such as drum kettles, gourd rattles, peyote "feathers," broadcloth blankets, otterskin headdresses, and even "Father" peyotes, which are a part of the altar arrangement at a peyote ceremony.

*Peyote.* Just as the war dance and stomp dance are the most important secular foci of pan-Indianism, so the peyote cult is the prime religious expression. Since the unifying effect of peyote has been discussed at some length by other writers, such as La Barre (8) and Petrullo (1), I shall not enter into great detail here. Nevertheless, one should note that there is a strong trend toward the standardized Plains "half-moon" ritual among the Oklahoma tribes at present. This seems to be a pan-Indian manifestation resulting from greater intertribal participation than was true in former years when, after the initial introduction of the cult, many more or less "tribal" fireplaces developed.

An intertribal peyote meeting that I attended in the summer of 1954 was attended by Southern Ponca, Kiowa, Comanche, Southern Sauk, Delaware, Oto, Pawnee, Southern Cheyenne, and Omaha adherents. La Barre (8) notes that many of the Eastern tribes now resident in Oklahoma, such as the Seneca, Creek, and Cherokee, have now taken up peyotism.

*Contributing factors.* Although the entire phenomenon of pan-Indianism may be regarded as a function of initial intensive acculturation, followed by a later "regrouping" as conditions became more stabilized, certain factors may be isolated that seem to have played a special role in its growth.

One of the principal factors fostering this intertribal solidarity is undoubtedly racial discrimination. Many whites tend to lump all tribes together, merely as "Indians." This, of course, elicits a complementary reaction. Although the Indian slums found in the cities of other states with large Indian populations are not so obvious in Oklahoma, yet a definite feeling of *apartheid* certainly exists.

The common economic level of most Oklahoma Indians, partially a result of the racial discrimination just noted, is also a major contributing element. Most Oklahoma Indians lease what little land they have and supplement the income thus derived, which is usually small, with wage labor performed for whites. The common poverty of members of different tribal groups undoubtedly

fosters a strong feeling of unity. This is well illustrated in the traditional remark of an Indian host to his mealtime guests: "We don't have much; we're just Indians."

In this connection it should be noted that the oil-wealthy Osage, although geographically in the vortex of pan-Indianism, participate in it to a much lesser extent than poorer neighboring groups. In their version of the war dance, the Osage "Man's dance," the long prayers, and other religious elements that have long been discarded by other groups are retained. The pan-Indian "feather" costume is viewed with disapproval by the Osage, and the more traditional "straight dancer" costume is worn even by the younger men. Some of these younger dancers, however, have recently adopted the "feather" style of dancing and costume but use it only when they attend the more pan-Indian powwows of other tribes. In the same connection it should be noted that the Osage are also resistant to the pan-Indian "half-moon" peyote fireplace, preferring the older (with them) "big-moon" variant.

The use of the English language as a *lingua franca* has likewise been instrumental in the growth of pan-Indianism. Indeed, many younger Indians do not understand any Indian language. At all Oklahoma powwows that I attended except those of the Osage, English was used by the announcer. Likewise, English is now the language spoken at peyote meetings, although sometimes a worshipper, after first excusing himself to the members of other tribes present, will pray in his native tongue. In 1954 a young Pawnee dancer admitted to me that he could not tell a Pawnee song from a Ponca one by its text. He was seen dancing vigorously to a Ponca tune that told of the killing of a Pawnee horse thief! Recently many stomp dance and round dance songs have been composed that have English words. These are great favorites among the young people.

Intermarriage between members of different tribes may be regarded as both a cause and an effect of pan-Indianism. The announcer at a stomp dance "shell-shaker" contest held in connection with a pan-Indian gathering at the Devil's Promenade, near Miami, Oklahoma, in 1954, was often hard put to give the tribal affiliations of the girls participating, although he was obviously acquainted with them or with their families. One contestant was identified as a Shawnee-Delaware-Wyandot. The winner of the war dance contest at this same gathering was part Osage and part Quapaw, and the winner of the straight dancer contest was a Creek-Osage.

Increased geographic mobility is another promi-



Fig. 2. An Oklahoma Indian girl in dancing costume, showing the "princess crown" headband.

nent factor that facilitates the intertribal exchange of ideas. Although Indians have always been fond of visiting one another, until recently the mere difficulty of transportation made it difficult to go far from home. With the advent of the fast car, however, such desires could be more easily indulged. Now it is not uncommon for Oklahoma Indians to make short visits to tribes in Nebraska, Iowa, and even Wisconsin at powwow time. The 1952 Ponca powwow was attended by delegations of Omaha and Winnebago from Nebraska and Ojibwa from Cass Lake, Minnesota, not to mention groups from almost all of the Oklahoma tribes.

Finally, I might mention Indian school contacts as a source of much pan-Indian feeling. Certainly the "Indian clubs" at schools such as Haskell and Chilocco have been responsible for a great deal of the intertribal exchange of songs, dances, and costume styles. La Barre (8) has discussed the role of Indian school contacts in the diffusion of the peyote cult.

*Summary and conclusions.* With continued acculturation there has been a tendency toward the loss of tribal identity in many Oklahoma Indian

groups. Instead of complete assimilation to white "American" culture, however, a pan-Indian culture has arisen. The principal secular focus of this culture is the powwow, centering around the war dance, stomp dance, and certain other dances and Indian activities. Its principal religious expression is in the peyote cult. Particular factors fostering pan-Indianism that may be separated from the general matrix of acculturation are (i) the mild racial discrimination found in Oklahoma, (ii) the common economic base of most Oklahoma Indians, (iii) intermarriage between members of different tribes, (iv) increased geographic mobility, and (v) Indian school contacts.

Pan-Indianism is, in my opinion, one of the final stages of progressive acculturation, just prior to complete assimilation. It may best be explained as a final attempt to preserve aboriginal culture patterns through intertribal unity. How long this pan-Indian culture will continue is dependent on a number of largely unpredictable factors, such as economic conditions, population shifts, and future miscegenation.

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7. A. Fletcher and F. La Flesche, *The Omaha Tribe, 27th Ann. Rept. Bur. Am. Ethnol.* (1911).
8. W. La Barre, *The Peyote Cult, Yale Univ. Pub. in Anthropol.,* No. 19 (1938).

*There is a very renowned argument much prized and much quoted by theologians, in which the universe is compared to a watch. Let us deal practically with this comparison. Supposing a watchmaker, having completed his instrument, to be so satisfied with his work as to call it very good, what would you understand him to mean? You would not suppose that he referred to the dial-plate and the chasing of the case behind, so much as to the wheels and pinions, the springs and the jewelled pivots of the works within—to those qualities and powers, in short, which enable the watch to perform its work as a keeper of time. . . . I do not wish to say one severe word here today, but I fear that many of those who are very loud in their praise of the works of the Lord know them only in this outside and superficial way. It is the inner works of the universe which science reverently uncovers; it is the study of these that she recommends as a discipline worthy of all acceptation.*—JOHN TYNDALL, *Fragments of Science,* vol. II, p. 94.

# Lost Art of Strad Varnish

## JOSEPH MICHELMAN

*Mr. Michelman, who was educated at Harvard University, is a research and consulting chemist and is president of Michelman Chemicals, Inc., 6316 Wiehe Road, Cincinnati, Ohio. He has been studying and playing the violin since childhood. His researches on old Italian violin varnish began as a hobby about 20 years ago and developed into a major pursuit. He is the author of the book* Violin Varnish *and several scientific and technical papers.*

SINCE the publication in 1946 of my researches (1) on the rediscovery of the "lost art" of making the old Italian violin varnish of Stradivari, the Amati, and so forth, a number of analyses of the varnish have been made with confirmatory results (2–7). Karl Letters (8), in Germany, has reported the analyses of the varnishes on five old Italian instruments, which also corroborated my work.

However, a brown-red varnish on a 'cello made by Francesco Ruggieri in 1691 has defied acceptable duplication heretofore. (Although the varnish is usually referred to as the old Italian violin varnish, it was also applied on 'cellos, violas, basses, and furniture, between the years A.D. 1550 and 1750, after which it completely disappeared from use without leaving any record of its composition or preparation.) Since a valid rediscovery of the lost art must be reconcilable with all the findings, a satisfactory preparation of this varnish is essential and would constitute another advance in the solution of this century-old mystery.

Spectrographic analysis of the varnish on the Ruggieri 'cello was reported in 1948 and revealed the presence of calcium in major proportions and silicon, copper, aluminum, potassium, magnesium, sodium, manganese, iron, and minor elements (3). Microchemical analysis indicated the presence of a coloring agent obtainable from madder root, a dyestuff much used in medieval times. This and the other analyses supported my proposals (1) that the resins in the old Italian varnish were metal rosinates, some colored by the dyestuffs in madder root.

Attempts to prepare satisfactory colored resins from calcium rosinate by fusion and precipitation methods (the two general methods for producing metal rosinates) were unsuccessful. Consideration was then given to the other metal elements, especially aluminum and iron, present in the analysis of the Ruggieri varnish, which had been regarded previously as "impurities." It is now established that aluminum rosinate can be colored by madder to yield a red resin and that iron rosinate yields a brown color that possesses excellent fastness to light in linseed oil varnishes (1). The formation of the brown-red resin from iron and aluminum rosinates can now be explained.

The precipitation method of preparing the metal rosinates, especially the colored resins, is so much easier and simpler than the fusion method that it more likely is the method that was used by the old Italian violin makers or the alchemists 400 years ago. Moreover, the precipitation method for preparing the colored resins is related to the ancient art of dyeing with mordant dyestuffs.

Numerous substances that were freely available in Italy during the period that the varnish was used and that contain the elements in the spectrographic analysis and possess the desired chemical properties were studied in an attempt to establish some pattern. Specimens of pozzolana, an interesting material containing "active silica" and of volcanic origin, were imported from Italy. Ochre, sienna, umber, and other earths were investigated. The raw material that was selected ultimately as the most suitable source for the precipitants for making the brown, colorless, orange, red, and red-brown resins was common brown clay. Clay is composed principally of aluminum silicate with variable amounts of silica and compounds of iron, calcium, magnesium, and so forth. The most likely reagents to extract these elements from clay, which were known and available about 1550, are aqua fortis (nitric acid) and aqua regia (nitric acid and ordinary salt or sal ammoniac, ammonium chloride).

## Precipitant for Brown Resins and Varnish

The precipitant for making the brown resins and varnish is prepared from brown clay dug a foot or two below the surface of the ground. The clay is air-dried and then roughly ground in a mortar and pestle, without further treatment. The only other material required to make the precipitant for the brown resins from clay is dilute aqua regia. In practice, 300 milliliters of 10-percent nitric acid,

30.0 grams of sodium chloride, and 300 grams of clay are mixed together and permitted to dry in the air on a flat plate for a week or two with occasional stirring. Placing the mixture in the sun accelerates the reaction and drying. The dried and powdered residue is then added to 1200 milliliters of water; this mixture upon standing a day or two yields a clear, yellow supernatant liquid, which can be removed by decantation. This liquid is the precipitant for making the brown resin; it contains aluminum, iron, calcium, and magnesium, but no silicon.

The brown resins are now easily prepared by adding this precipitant to an alkali rosinate solution, as was previously described (1). The brown varnish is then prepared by dissolving the resin in turpentine (in which it is freely soluble) and adding linseed oil, preferably boiled oil. Exposure of such varnish films to sunlight will develop the brown color, which has been reported (1).

## Precipitant for Colorless and Colored Resins and Varnishes

To prepare the precipitant for making the colorless and colored resins and varnishes, the clay is digested with dilute aqua fortis, nitric acid alone; in practice, 300 milliliters of 10-percent nitric acid and 300 grams of clay are mixed together as in the preparation for brown resins. The dried and powdered residue is then gently heated—for example, on a water bath—for about 6 to 12 hours, before its addition to 1200 milliliters of water. The clear, water-white supernatant liquid obtained after the mixture stands a day or two is practically free of iron and contains aluminum, calcium, and magnesium, but no silicon. Ten milliliters of this clear solution acidified will show only a faint coloration with potassium sulfocyanide reagent. This is the precipitant for making the colorless and colored resins.

The colorless resin and varnish are made in the same way as the brown resin and varnish. The orange and red resins are prepared by dyeing the colorless resin with madder root extract. The concentration of the coloring agents determines whether the resulting resins will be orange or red. The presence of some iron in the precipitant, as the result of insufficient heating, will produce the brown-red resin such as that which could have been used in the varnish on the Ruggieri 'cello.

## Suitability of Clay

The use of common clay as one of the raw materials for making the "'glorious varnish of Stradivari and Cremona" may appear incongruous to many people; hence, some additional explanation

is appropriate. Moreover, the preparation of the precipitant from dilute nitric acid, salt, and clay was surprisingly fortuitous from a chemical standpoint, inasmuch as the old Italians obtained their results empirically and without the benefit of analytic control and without any knowledge of the principles and the reactions involved.

The preparation of the precipitants from clay is very simple. The concentration of acid is of little consequence, because any excess is expelled or decomposed in the drying operation:

$$NaCl + HNO_3 \rightarrow NaNO_3 + HCl$$
$$4HNO_3 + 3NaCl \rightarrow 3NaNO_3 + Cl_2 + NOCl + 2H_2O$$
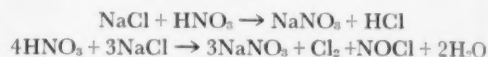
The $p$H of the precipitant made from clay and dilute aqua regia as described averages 2.0. The ratio of aluminum to iron in common clay is favorable for making the brown resin; the presence of calcium and magnesium rosinates would also reduce the intensity of color imparted by iron rosinate. It is possible to prepare a precipitant from common clay that is practically free of iron; this is very important in making the colorless and colored resins.

Clay, pozzolana, and the earths studied contain large amounts of silicate, but none yielded acid extracts containing silicon, as was expected, in the colloidal state. The conditions of the preparation and the presence of adverse polyvalent ions may have precipitated the silicic acid, which was probably liberated in the form of a negatively charged colloid.

## Presence of Silicon in the Varnish

As has been reported (7), the presence of silicon in the old Italian varnish was due to the wood ashes from which the ancients derived their alkali. This is now supported by the fact than no silicon was found in the precipitants—the only other source that might have supplied this element. However, the amounts of silicon were not sufficient by the methods suggested previously to account for the silicon when it is present as one of the major elements in the spectrographic analyses.

During further study of the water extracts from wood ashes, it was observed that such solutions contain silicate, whereas causticized wood ashes (treated with milk of lime) contain little if any; the silicate is precipitated as calcium silicate. It was then learned that a satisfactory alkali rosinate solution could be prepared merely by extracting the alkali from wood ashes with water, without the addition of lime, and then dissolving rosin in the lye thus obtained. This further simplifies the preparation of the resins and accounts for the presence of silicon in the analyses at the same time.

## Alkali Rosinate Solution

To extract the alkali from wood ashes, 800 milliliters of water and 80 grams of wood ashes are mixed together and stirred or shaken occasionally for 2 or 3 days. (Ashes obtained from wood that had been exposed to rain and snow were found to contain much less alkali than ashes from wood that was not subjected to the leaching action of water.) The extract is decanted and filtered through cloth; the lye thus obtained contains carbonate and silicate. On the average, 10.0 milliliters of filtrate required 30.0 milliliters of 0.1N hydrochloric acid for neutralization to methyl orange and is thus 0.3 normal alkali.

To prepare the alkali rosinate solution, 600 milliliters of lye is mixed in the cold with 80 grams of freshly crushed rosin, a large excess. After this mixture stands for several days with occasional shaking, a semitranslucent, somewhat viscous solution results, from which the undissolved rosin is easily filtered off through coarse cloth. The pH of this alkali rosinate solution is about 8.6, indicating that the carbonate has been neutralized to bicarbonate.

The alkali rosinate solution thus prepared has the interesting property of being compatible with ethyl alcohol in certain proportions. Two parts of this solution and 1 part of alcohol (No. 3-A) by volume yield a thin, clear mixture. This is fortunate and desirable when the alcohol extract from madder root (1) is added to the alkali rosinate solution in the preparation of the colored metal rosinates.

The wood ash alkali-rosinate solution mixed with an excess of the acid extract from clay yields resins that are freely soluble in turpentine, which deposits clear films upon drying. Silica is present in the ash of such resins, indicating that silicates have also been precipitated in the preparation of the metal rosinates and then appear in the final varnishes because of the peptizing effect of the metal rosinates. Since bicarbonate is present in the alkali rosinate solution, the addition of solutions of aluminum and iron compounds should produce basic resins of the type $Al(OH)_2$ (rosinate) and $Al(OH)$ (rosinate)$_2$, for the formation of which some evidence has been found.

## Conclusions

The preparation of the old Italian varnish has been reconstructed (9) on the basis of the most reliable and acceptable analytic data available today. Clay or similar earths were treated with dilute nitric acid with or without salt to prepare one solution. Wood ashes were extracted with water, and the resulting lye was used to dissolve ordinary rosin to prepare the other solution. Mixing the two solutions together yielded the various resins (metal rosinates). Dyeing some of these resins with an extract from madder root supplied the colored resins. A solvent (turpentine) and a drying oil (boiled linseed oil) were the remaining ingredients of the varnish. From these lowly materials and by these simple methods, the old Italian luthiers, four centuries ago, created their beautiful varnish.

## Modern Adaptations

It was originally proposed (1) that the old Italians used aluminum (alum) and iron (copperas) compounds to prepare the precipitants for making their resins. This is confirmed by subsequent research, the only difference being that chlorides and/or nitrates of these elements were more likely used, instead of sulfates; but this is immaterial. The original suggestions for preparing the precipitants are still valid. Calcium compounds can be added to the precipitants if desirable.

The other difference is that causticizing the wood ashes with milk of lime, as was practiced by the ancients to produce potassium hydroxide, is not necessary. Rosin can be dissolved in about 0.3N potassium carbonate, 20.7 grams of $K_2CO_3$ per liter. The value of silicon compounds in the varnish has not been definitely established; sodium silicate, (dilute water glass) can be added easily to the alkali rosinate solution before precipitation, if it is found to be beneficial.

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*The history of a science is the science itself.*—GOETHE.

# Structure of a Classic Raw Material

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WOOD is a living and heterogeneous material. Its structure and properties are not sharply definite or constant but vary over a wide range and depend on the age and growth of the tree. The study of wood structure gives us the basic knowledge on which the immense field of wood technology is based. Wood chemistry is now undergoing a period of great development and is finding ever more uses for this basic raw material. In this article we will examine some aspects of the structure of wood in order to obtain a closer insight into the special properties and characteristics, and perhaps even the beauty, of this great natural product (1).

### Formation of Woody Tissue in the Stem

The anatomical examination of a cross section of a young lime stem may begin at the marginal zone of the bark (Fig. 1a) and follow the rays in their radial direction toward the pith. The stem is protected against most influences of the surrounding world by the epidermal tissue, a product of the cork cambium. Figure 2 shows some of the marginal cells of the stem, with the epidermis—a layer of thick-walled cells—joining some elements of the periderm. Under the meristematic tissue (cork cambium-phellogen) there are collenchymatous and parenchymatous cells (Fig. 3), surrounding the phloem with the pericycle. In a young stem, the parenchymatous tissue is an important organ of assimilation, but, in an older and less active stage, it becomes a storage place. (Note the starch grains in the parenchyma cells in Fig. 3.) The wood of *Abies* does not contain large quantities of resin, but in the bark we can recognize canals that are formed by parenchymatous cells and thin-walled epithelial cells (Fig. 4). In sharp contrast to the rather sparse cell-wall formation in the epithelium of the resin ducts are the thick-walled cells of the pericycle (Fig. 5). These cells are shown in a cross section through a young stem of *Populus,* where the mechanical elements are distributed in several groups. In their younger development these cells

have two or three lignified cellulose membranes, which become thicker in a later stage until they fill up almost all the lumen of the cells.

The typical difference between phloem (Figs. 6 and 7) and xylem cells (Figs. 8 and 9) is easy to recognize. The phloem is a transmissive tissue that has conductive elements and cells with a mechanical function. To the first group belong the sieve elements. The sieve tubes are long, cylindrical cells with perforated end walls and sieve plates in the top region of the side walls. The sieve-tube system allows the products of assimilation to flow from the leaves through the twigs into the stem. Generally the sieve tubes function during only one or two growing seasons. After that, a so-called "callus plate" closes the perforations, and the conductive cells are no longer active (Fig. 10). The photographed callus plate seems to stretch over the sieve plate like a bridge over a river. It is also interesting to note that the marginal zones of the perforated plate are darker than the middle area. The phloem fibers serve as mechanical elements, and in conifers they are arranged in radial rows. Some of the cells in Fig. 7 contain some plasma and collapsed cell nuclei. The cells with irregular shape have thicker tangential walls than radial walls. A small portion of phloem cells are still parenchymatous with very thin walls, little plasma, and small nuclei. The xylem fibers of *Populus* (Figs. 8 and 9) are more or less regular in shape and arrangement. In Fig. 8 some ray cells are visible, and in one of them a large, simple pit can be seen. The older xylem cells (Fig. 9) are not so thin walled but show a well-developed secondary membrane, which in mature wood is even thicker than that shown in the electron micrograph.

Between the xylem and the phloem appear rows of equally formed cells, constituting the meristematic tissue (the cambium). These elements are the progenitors of both the xylem and the phloem, and for this reason they are extremely important in the life of the tree.

*The cambium, its significance and activity.* The
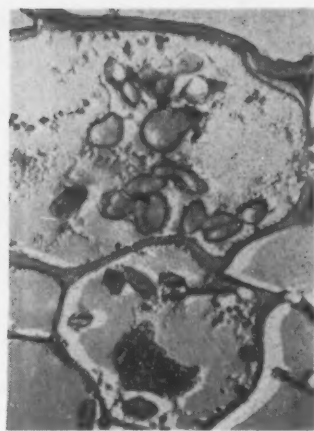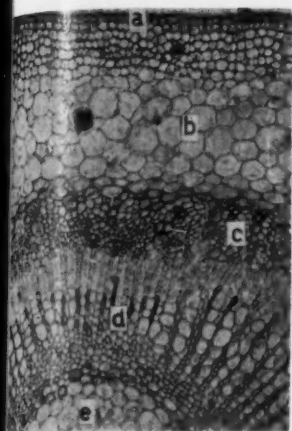
Fig. 1 (left). Cross section through a young lime stem: (a) epidermis, (b) cortex and parenchyma, (c) primary phloem, (d) primary xylem, and (e) pith. (×80) Fig. 2 (center). The outer portion of the cortex in a young *Abies* plant. (a) Thick-walled epidermis and (b) phellogen-cork cambium. (×1300) Fig. 3 (right). Parenchymatous tissue in the cortex of *Abies*. The cells contain starch grains. (×1400)
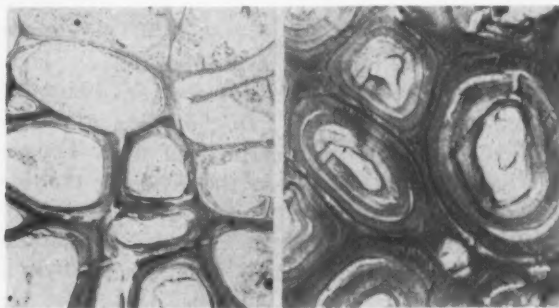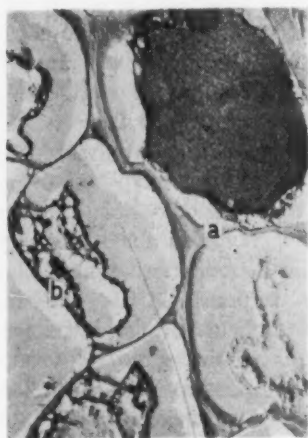


Fig. 4 (left). Part of a resin duct in the bark of *Abies* (transverse section). (a) Thick-walled surrounding cells of the duct and (b) thin-walled epithelial cells. (×2000) Fig. 5 (right). Thick-walled cells of the pericycle of *Populus* sp. in a young (×1000) and a mature stage. (×1750)
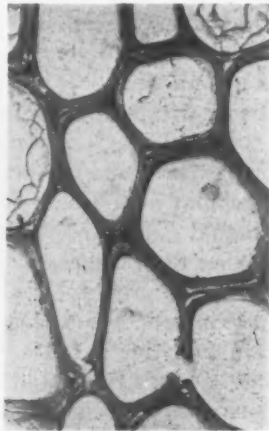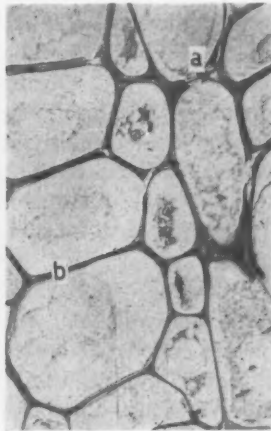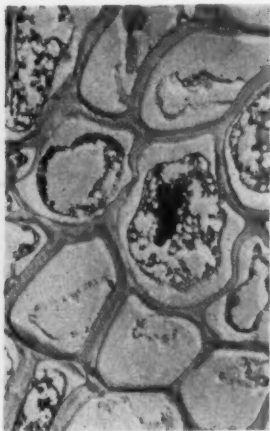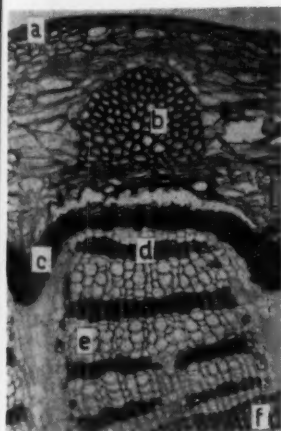


Fig. 6. Cross section through the secondary phloem of *Vitis* with (a) cortex, (b) group of primary phloem, (c) sclerenchymatous layer, (d) phloem fibers, (e) sieve tubes, and (f) xylem. (×60) Fig. 7. Phloem parenchyma in *Abies*. (×1500) Fig. 8. Xylem elements in a young *Populus* stem. (a) Ray cells with primary pits and (b) fibers. (×1000) Fig. 9. Xylem elements of the same stem in an older stage. (×1500)
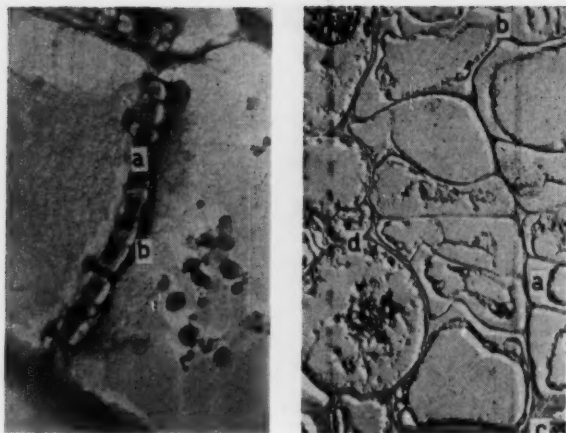
Fig. 10 (left). Callus plate in a sieve tube of a young *Abies* stem. (*a*) Sieve plate and (*b*) callus. (×2750). Fig. 11 (right). Transection through the cambium zone of a young *Abies* stem. (*a*) Cambium cells, (*b*) xylem daughter cells, (*c*) phloem daughter cells, and (*d*) ray cells. (×1500)

cambium produces new cell material by normal cell division. The dividing meristematic cells are continually forming new daughter cells that develop new phloem elements in the neighborhood of the phloem; on the opposite side near the xylem, the new daughter cells differentiate into xylary elements. The xylem side of the meristem divides more rapidly than the phloem side. The first result of this differential growth is the development of conspicuous, broad xylem tissue in contrast to the rather sparse development of the phloem. A second result, which can be seen only under a microscope, is the difference in cell-wall thickness of the elements near the cambium. On the phloem side, they are thicker than the xylem cell walls that are the same distance from the cambium (Fig. 11). Since the meristematic cells produce more elements of the wood tissue, they have no time to grow in thickness. They grow first in length and only later become thicker. During the growth in thickness of a stem, its circumference becomes larger and larger. The epidermal tissue breaks up, and new material is formed. The cambium itself would split in the same manner if it could not follow the increase in growth by division in the tangential direction.

In the primary stage of development of the meristematic tissue in a young stem of *Abies,* the cambium ring is not completely closed but occurs only in the vascular bundles. Figure 11 shows a small portion of the vascular tissue in which the cambial cells lie in the center, running diagonally from the right to the left side. Beneath that meristematic layer, we recognize the xylary tissue (Fig. 11*b*) and the phloem (Fig. 11*c*). Ray cells cross all the de-

scribed layers in the radial direction. The cambial mother cells are rectangular and more or less constant in their shape and dimensions, except that the initial cells of rays are smaller than the other cambial cells and circular in form. These two cell types of cambium can be observed in any wood and are characteristic of meristematic tissue. The distribution of the ray initials in the meristem is, therefore, important for the arrangement of the rays in the wooden tissue. The structure of the xylem is, like the figure in a mirror, similar to the structure of its meristematic tissue. The form and significance of cambium cells have been adequately described by J. W. Bailey (2).

## Anatomy of Coniferous and Dicotyledonous Wood

The differences between softwoods and hardwoods are so obvious that it is not difficult to classify them. The structural make-up of softwood is not as apparent as it is in hardwood.

The three functions of a stem are mechanical support, water transport, and storage. These functions result in a division into three types of tissue. Thus, wood does not have a homogeneous construction but has three different types of tissue that are connected, each serving the whole in its own special manner. The tracheids in the softwoods and the fibers in the hardwoods, both typical longitudinal elements, are responsible for the mechanical strength. The tracheids are also the water-transporting elements in the softwood group. In the more highly developed hardwoods, the longitudinal vessels also serve this purpose. Finally, in both types of plants, the horizontal ray cells and the vertical



Fig. 12. Schematic drawing of a fir stem section, showing (*a*) the cross section, (*b*) the radial section, and (*c*) the tangential section. Also shown are (*d*) rays, (*e*) bark, and (*f*) resin ducts.

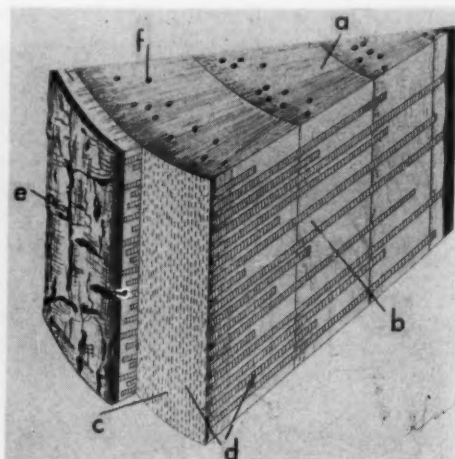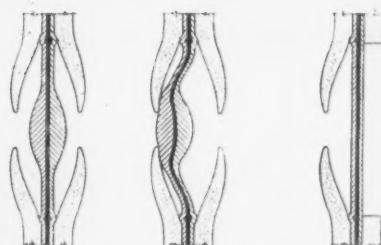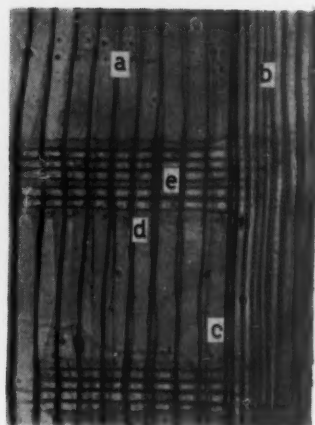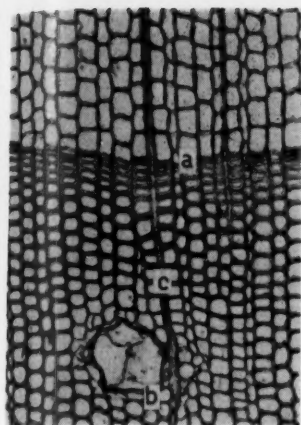Fig. 13 (left). Cross section of *Pinus strobus*. (*a*) Growth ring boundary with early and late wood, (*b*) resin duct with epithelial cells, and (*c*) medullary ray. (×65) Fig. 14 (center). Radial section of *Pinus strobus*. (*a*) Longitudinal tracheids in early wood, (*b*) longitudinal tracheids in late wood, (*c*) bordered pits, (*d*) ray tracheids in marginal rows with bordered pits, (*e*) ray parenchyma with window-like pits. (×65). Fig. 15 (right). Diagram of a bordered and semibordered pit. At the left, the torus is in the median position; in the middle the pit is closed by the torus. [From *Textbook of Wood Technology* (*3*)].

parenchyma strands store the products of assimilation.

For the discussion of wood anatomy *Pinus strobus* has been chosen as an example of the softwood group and *Betula verrucosa* as a hardwood species. Both are well-known trees, and the important and characteristic features of the two groups can easily be pointed out. Figure 12 demonstrates a small sector of a stem disk. The occurrence of resin ducts and the absence of special pores for water transport are characteristic of softwood species. In this three-dimensional drawing there are three especially interesting surfaces that differ in their structure, according to the occurrence of the vertical and horizontal elements. The three views represent a cross section, a radial section, and a tangential section. The arrangements of the cell elements can be summarized as follows.

(i) In a cross section, the vertical elements of the stem are cut across the grain and the horizontal elements are cut longitudinally.

(ii) In a radial section, the vertical and horizontal elements of the stem are cut longitudinally.

(iii) In a tangential section, the vertical elements of the stem are cut longitudinally and the horizontal elements are cut across the grain.

*Structure of Pinus strobus.* The northern white pine is a well-known member of the softwood group and can be used as a typical example of softwood anatomy. As mentioned earlier, only two types of tissue can be found in this kind of wood. The longitudinal tracheid elements perform the functions of both mechanical support and water transport. The horizontal rays serve mainly for storage and contain the various heartwood components. Figures 13, 14, and 15 point out the three main

directions: the cross section and the longitudinal section in both radial and tangential directions. The minute structure of this wood will now be examined.

*Cross section.* The growth rings that can be observed with the naked eye on a cross section of a wood sample occur in a microscopic preparation as broad zones, and they are bordered by the thick-walled cells of the late wood. In the early part of the growing season, the new tracheids, which are produced from the cambium, become thin-walled and wide elements. Therefore they serve principally for water transport. The width of the early wood zone depends on a number of factors in the tree's environment and particularly on the climate during the growth period. At the edge of this zone, the tracheids change their form in the cross section from the polygonal shape to a more or less rectangular shape. They are now thick walled and rather tightly packed and have assumed their mechanical supporting function. The radial arrangement of the tracheids signifies that they are all products of the same cambial mother cell at the beginning of each radial row, and, again, this is a characteristic feature of the softwoods (Fig. 13). The tracheids are longitudinal elements that, in some species, may attain a length up to 4 millimeters and are 90 to 100 times longer than they are broad. The very length of the prosenchymatous elements of the softwood qualify these woods for use in the paper industry. The long cells felt easily and give the paper the special mechanical properties that are needed.

Other longitudinal elements that can be observed in the cross section of *Pinus strobus* are the resin ducts. They do not occur regularly in a growth

zone. In some species they may be more frequent in the late wood than in the early wood or they may be at the margin of the growth ring rather than in the inner part. They are not as narrow as the tracheids and are surrounded by several thin-walled cells. In botanical terminology, their origin is described as a schizogenous development. This means that near the cambium groups of meristematic daughter cells (tracheids) remain parenchymatous. Their cell walls do not grow in thickness and are not lignified. When a resin duct develops in these groups, the middle lamella between the cells in the center of the group splits, and the resulting cavity is filled with resin from the surrounding cells. These cells keep producing resin and, therefore, remain thin walled. They divide along their longitudinal axis and form the so-called epithelium of the resin duct.

As we shall see in the discussion of the tangential section, there are also horizontal resin ducts that anastomose with vertical ducts. The resin within the system of canals is under a certain pressure. When the system is damaged at any place, the whole resin production of the tree tends to move in that direction. This fact is very interesting for the industrial harvesting of the resin. The trees, mostly pine trees, can be tapped in a special manner at the base of the trunk, and the resin flows into cups placed near the wound. The occurrence of the resin ducts and the formation of their epithelial cells are very useful features for the identification of softwoods.

The rays are the most important horizontal elements in the tree. They conduct water and sugar solution in the radial direction, and they can transform the sugar into starch, and, inversely, they can transform the storage product starch into transportable sugar. In the cross section they occur as narow bands that run parallel to the tracheid rows and cross the growth rings at right angles. Their cells are small and long, sometimes occurring with bordered pits, and sometimes with only simple pits, depending on the type of cells that are present. The rays are uniseriate and, therefore, in the cross section are only one cell broad. The only exceptions are the rays that contain a horizontal resin duct. When the resin canal portion of the ray is sectioned, two or more rows of epithelial cells are visible.

*Radial section.* In the radial section we observe both the longitudinal and the horizontal elements sectioned along their longer axis. The longitudinal elements, tracheids, and resin canals run vertically, and the rays run horizontally. The narrow and thick-walled late-wood tracheids once again form the boundary of the growth rings. The ends of the tracheids are not very pointed and are not arranged in horizontal lines. This means that *Pinus strobus* does not have a storied structure; the tracheids are placed individually in their longitudinal direction. This fact is mainly the result of the individual growth of the cells after their formation in the cambium. The rich frequency of bordered pits in the early wood, especially in the end zones of the trachial elements, is a guarantee of a good contact between two cells. Therefore, the pits have an important significance for water transport in softwoods.

If two neighbor cells are compared with two rooms and their cell walls are compared with the wall between the two rooms, then the bordered pits are comparable to doors leading from one room into the other. In Figs. 15 and 16 a bordered pit is shown in cross section. The secondary walls of both cells form the pit chamber, with its aperture leading into the cell lumen. In the center of the pit, the two primary walls and the middle lamella divide the pit chamber into two equal parts. The center of the pit membrane is reinforced from both sides with cellulosic material. This so-called torus is larger than the aperture (the porus) and, in a surface view, is similar to a disk lying on the pit membrane. In this type of construction, the pit acts as a valve; the pit membrane with torus is movable and can close the right or the left aperture (Fig. 15). In the central position of the membrane, the water can pass on both sides of the torus from one cell to the other. Because this passage is so narrow, the water must make its way through the fine network of the primary walls.

Figures 17 and 18 demonstrate a whole pit in a
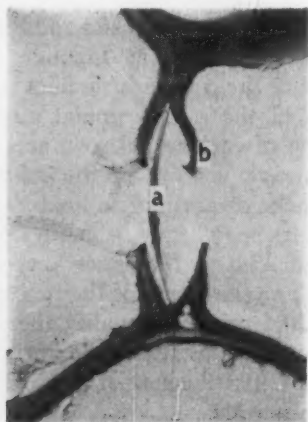


Fig. 16. A bordered pit in the transverse section, showing (*a*) torus and (*b*) secondary wall, forming the pit cavity. (× 2500)
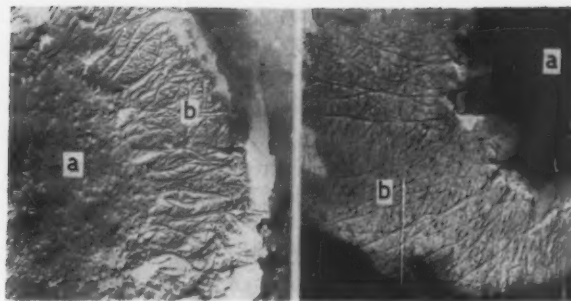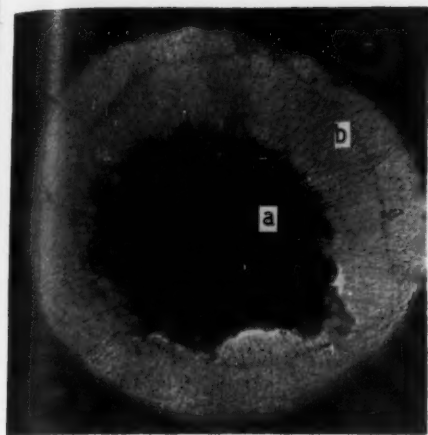
Fig. 17 (left). Section through a bordered pit, showing (a) torus and (b) membrane. (×9000) Fig. 18 (right). Details of bordered pits, showing (a) torus and (b) membrane. (Left, ×12,500 right, ×15,000)

surface view and a smaller portion of a pit at a higher magnification. The membrane has a compound structure; there is a normal primary wall with a netlike woven texture. This wall is reinforced with special cords (aggregated fibrils) that run out from the torus in a radial direction to the end of the membrane. The torus itself does not have a smooth surface, but rather a circular arrangement of fibrils, and looks like any cellulosic cell wall.

This description of bordered pits has been emphasized to show what amazing beauty can be seen in the fine details of wood. But disregarding this esthetic consideration, pit structure is a striking problem in the impregnation industry. It is necessary to preserve wood against fungal decay. Therefore, the timbers are impregnated with certain fungicides that are pressed into the wood. This method is not very difficult to apply in certain hardwoods, but in the softwoods the bordered pits create a real problem, because, in old wood that no longer functions for water transport, the pit membrane stays on one side of the pit chamber and closes that door entirely. No water and no impregnation solution can pass these canals, and the wood in the inner regions of a stem cannot be preserved.

It would be a very interesting scientific and commercial discovery if someone could find a process to open these pits by some treatment of the wood that would enable the impregnation solution to enter the cells without difficulty. Since a long tracheid has a great number of bordered pits, the effectiveness of such a treatment would be obvious. In a comparison of the late-wood and early-wood tracheids, it is easy to observe that on the radial section the late-wood cells have fewer bordered pits than the early-wood cells and that the pits in the small elements of the late wood are also smaller.

In the radial section we not only get a complete idea of the structure of the bordered pits, but we are also able to study the interesting arrangement of the horizontally orientated rays. The procumbend cells of the rays are seen longitudinally, the same as in the cross section. Since the rays are uniseriate, each ray cell touches a cell of the longitudinal tissue and, therefore, is in connection with that cell. The doors from the ray cells to the tracheids are again the pits, but now the borders are not uniform and the bordered pits can be distinguished from semibordered ones (Fig. 15). These two types of pits differentiate two types of ray cells: the ray tracheids and the ray parenchyma cells. The ray tracheids form the two margins in one or more cell rows in the majority of all rays of Pinus strobus. Occasionally they may also occur in the middle of the ray. In every case the ray tracheids can be identified by the occurrence of small bordered pits that lead from one ray tracheid to another as well as from the ray tracheids to the longitudinal tracheids. The ray tracheids are components of the conductive tissue. They transport water from the bark to the inner zones of the stem.

The ray parenchyma cells belong to the storage tissue and contain starch. A characteristic feature of the parenchyma cells is the simple pits in their walls. These pits differ from the bordered pits in the following ways: (i) the secondary walls do not form a pit cavity, as was shown for the bordered pits, and (ii) the pit membrane does not have a torus in the center (Fig. 15). These differences can be readily seen in the radial section, in the pits between the ray parenchyma cells and between parenchyma cells and tracheids. First we observe the absence of the secondary wall in small areas, and, in the cross fields of ray cells with tracheids, we see the very conspicuous, windowlike pits.

The ray parenchyma cells are about the same length as the ray tracheids; most of them are rectangular in shape or have oblique end walls. The few rays that contain resin ducts in the radial section look the same as in cross section when their canal portion is sectioned. In the center of the ray, there are rows of epithelial cells with thin walls and cylindrical shape.

*Tangential section.* In the tangential section the longitudinal elements are shown lengthwise and the horizontal elements are cut across their main axis. The main difference between the tracheids in the tangential view (Fig. 19) and those in the radial section is the extremely small number of bordered pits on their tangential walls. Furthermore, no growth rings are visible in this surface, because the section lies parallel to the rings. The vertical lines of the tracheid's radial walls look like ropes of pearls in the end region of the vascular cells because of the cross-sectioned bordered pits. The rays are small and uniseriate and differ only in their height.

The distinction between ray tracheids and ray parenchyma cells is not as easy in the tangential section. The two types of pits are again characteristic of the two cell types. The distribution of the rays in the wood is irregular and does not follow any special rule. The same is true for the distribution of the horizontal resin ducts, which can be recognized in the central portion of some rays. Where they occur, the center of the ray is broader and the whole ray is spindle shaped. The epithelial cells in the inner part are very thin walled and fill up the whole canal in the later stages of development.

The anatomy of *Pinus strobus* is characteristic
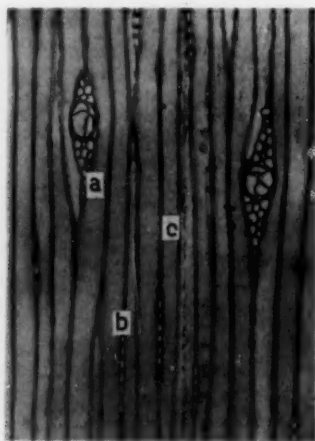


Fig. 19. Tangential section of *Pinus strobus.* (*a*) Ray with resin duct, (*b*) simple ray, uniseriated, and (*c*) tracheids with bordered pits on their radial walls. (×65)
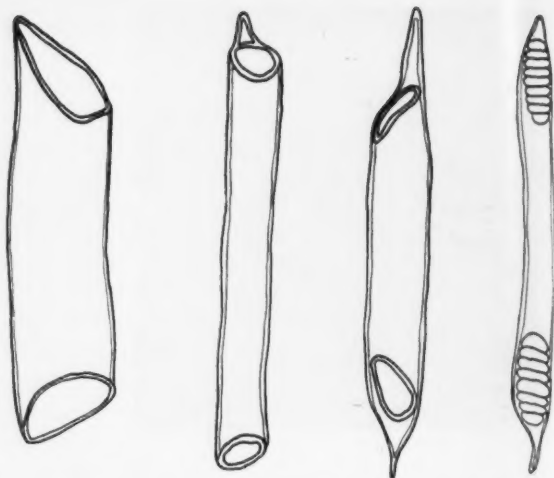


Fig. 20. Diagram of some vessel types, showing the different forms and perforations.

of the softwoods, but there are other types of coniferous wood that vary somewhat in regard to finer details. The variation of these features is important in the identification of unknown timbers.

*Structure of Betula verrucosa.* The easiest way to distinguish between hardwood and softwood species is to observe the differences in the two water-transporting systems. The water transport in conifers is confined to the wide early-wood tracheids; since the transpiration of the softwoods is rather small, this little specialized conductive system is good enough. On the other hand, the need for water in the hardwood group is much greater. It is said that in the small area of about 3 acres of birchwood more than 30,000 liters of water is transported from the soil through the stem to the leaves in one warm, air-dry day. Furthermore, the stem wood itself keeps a remarkable amount of water in its capillary system and in its cell walls. It is obvious that these large quantities of transported water demand a highly specialized and highly capable system of conduction. This task is met by cells with a large diameter and with special end-wall constructions, if end walls exist at all, that form long tubes in the stem. These pipe lines facilitate water transport and conduct these great quantities of water to the leaves.

The vessel members, or pores as they are called, vary greatly in their shape, dimensions, construction of end walls, and pitting. Figure 20 gives some information on the main types of vessel-member construction: the length of the cell members varies with the species and even within each stem. The wide middle portion of the pore is perforated by a great number of pits, as are other pores, fibers and
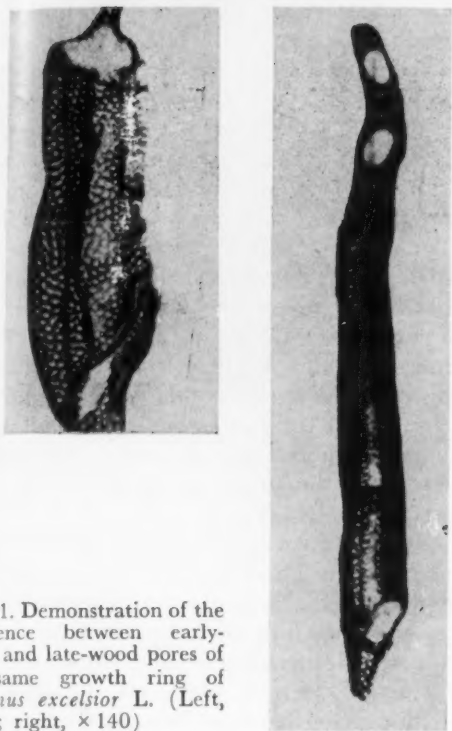
Fig. 21. Demonstration of the difference between early-wood and late-wood pores of the same growth ring of *Fraxinus excelsior* L. (Left, ×200; right, ×140)

ray cells, which allow near contact with the surrounding elements. The end walls of the pores are mostly oblique, perforated, or simple, and, in general, very scarce. Some vessel members show two overlaps on each side, which bring to mind the two similarly shaped ends of the mother cell in the cambium.

Figure 21 demonstrates the great differences between the vessel members within one species. These pores of *Fraxinus excelsior* are typical: the wide one in the early wood and the long one in the late wood. The wide range of differences in one cell element gives us a new insight into the complexity of the plant body. A special vessel-member type and its arrangement in the growth rings are characteristic of each species (Fig. 22). These cells are highly significant in the identification of timbers, and because their form and dimensions are so different from the other cell elements in the tree, they are objects of special study. The interesting point in their development is their growth in width.

A further physiological property of the vessels is interesting as well: these cells do not keep their activity during the whole life of the tree, but they serve in most timbers only during a small number of vegetation periods. In some species they are closed after their water-conductive period is over by very thin-walled cells, called tyloses. These cells grow out of the surrounding parenchymatous tis-

sue and into the pits. The closing of the water-conductive system has its practical significance in timber impregnation. It is obvious that the wide pores allow the impregnation substances to penetrate easily and far into the wood. Conversely, all species that form tyloses in their heartwood are rather difficult to impregnate.

*Cross section.* The description of the cross section of a hardwood should be started by mentioning the most obvious feature: the water-conductive system. The vessel members vary not only in their shape and dimensions but also in their arrangement in the growth ring. In some timbers great differences occur in early-wood and late-wood pores; in other species these variations are not so obvious. The definitions for the following classification of timbers according to pore arrangement depends, therefore, on the occurrence of early-wood and late-wood differences.

1) *Ring porous wood* (Fig. 23, left). The large early-wood pores are arranged in tangential rows along the growth-ring boundary. In the late-wood portion of the growth ring, the vessels are much smaller and irregularly distributed in the fiber body.

2) *Semiring porous wood* (Fig. 23, center). The difference between early-wood pores and late-wood pores is small. Most of the vessels are arranged irregularly, except for one tangential row of pores in the early-wood zone along the growth-ring boundary.

3) *Diffuse porous wood* (Fig. 23, right). There is practically no difference in diameter between early-wood and late-wood pores, and all vessels are irregularly distributed.

*Betula verrucosa* is a species of the diffuse porous
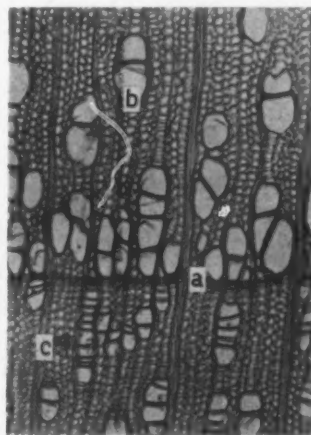


Fig. 22. Transection of *Betula* spec., showing (*a*) the growth-ring boundary, (*b*) some vessels, and (*c*) a medullary ray. (×65)
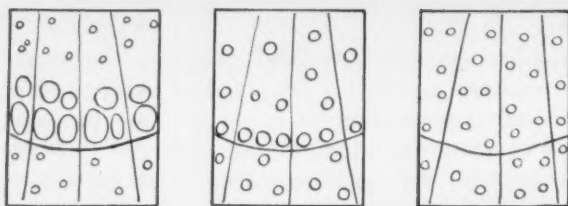
Fig. 23. Variations in the arrangements of pores: ring porous (left), semiring porous (center), and diffuse porous (right).
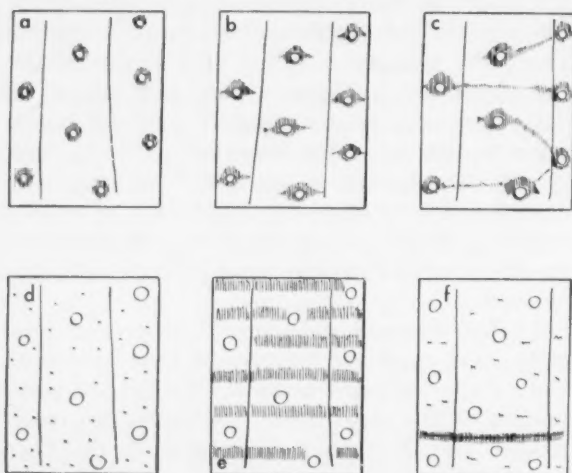


Fig. 24. Schematic drawing of the parenchyma arrangements, showing the paratracheal group: (*a*) vasicentric type, (*b*) aliform type, and (*c*) confluent type; and the apotracheal group: (*d*) diffuse type, (*e*) metatracheal type, and (*f*) terminal type.
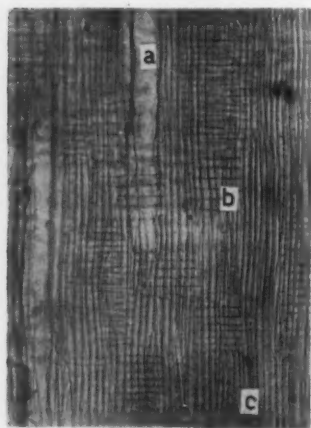


Fig. 25. Radial section of *Betula* sp., showing (*a*) multiple perforation plate, (*b*) ray cells, (*c*) fibers. (×65)
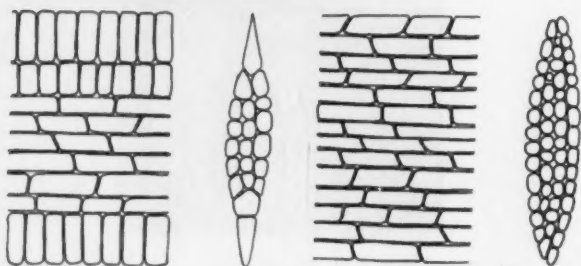


Fig. 26. Homogeneous (left) and heterogeneous (right) rays shown schematically.

group; its vessels are irregularly distributed and no obvious difference in pore diameter occurs. But there exists another feature in the vessel arrangement: the grouping of pores. In the entire growth ring radial groups of two to four pores occur between the solitary pores. The cross section also shows a rather scarce late-wood zone of only a few cell rows, where the rays become a little broader. The medullary rays occur in two different sizes, but their breadth varies only within a small range. In softwoods the tracheids are, for the most part, arranged in strictly tangential rows. This radial pattern is disrupted in the hardwoods by the immense growth in width of the vessel members. The fibers are more or less thin walled and irregularly formed in the early-wood zone, and in the small late-wood zone they follow the growth-ring boundary with the longer axis of their rectangular form.

The storage tissue has an important function in the life of a tree. The parenchyma system is highly developed, especially in the hardwoods. The arrangement of the thin-walled parenchyma cells is again a significant feature in wood anatomy. A comparison of the different types of parenchyma distribution may, therefore, be of some interest. A first point in classification must be the determination of whether or not the parenchyma stays in close contact with the water-transporting system. The storage tissue is said to be *paratracheal* when its cells surround the pores and stay in direct contact with one another. In the *apotracheal* type of arrangement, the parenchymatic cells lie between the conductive elements. For the most important groups, the following definitions are in accordance with the descriptions of the Committee of Nomenclature of the International Association of Wood Anatomists.

*Paratracheal group:* (i) *Vasicentric* type (Fig. 24*a*). The paratracheal parenchyma forms a vascular sheath of variable width and appears circular or oval in cross section. (ii) *Aliform* type (Fig. 24*b*). The vasicentric parenchyma is extended on each side by two wings and, therefore, has an eye-like appearance. (iii) *Confluent* type (Fig. 24*c*). As a further development of the aliform type, the parenchyma coalesces in the tangential direction, forming irregular tangential or diagonal bands.

*Apotracheal group:* (i) *Diffuse* type (Fig. 24*d*). The parenchyma cells are distributed irregularly over the whole cross section. They do not touch the vessels but form a coalescent system in the longitudinal axis of the stem. (ii) *Metatracheal* type (Fig. 24*e*). Aggregated wood parenchyma that forms concentric laminae, primarily independent of the vessels. (iii) *Terminal* type (Fig. 24*f*). Ag-
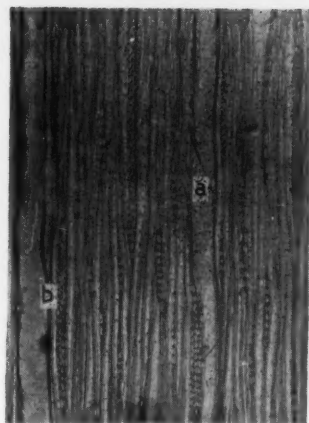
Fig. 27. Tangential section of *Betula* sp., showing (*a*) multiple perforation plate and (*b*) ray cells. (×65)

gregated wood parenchyma that forms a more or less continuous layer of variable width at the close of a season's growth.

The occurrence of a well-developed parenchymatic tissue is characteristic of the hardwoods, but the tissue is not so sharply divided into one of the given types. In birch the storage tissue is rather scarce and follows the diffuse type of distribution.

*Radial section* (Fig. 25). In the radial section the vessels can be seen in their longer axis and show clearly the interesting ladderlike perforated end walls, where 10 to 20 bars occur. The vessel members do not vary much in length—a characteristic feature of the diffuse porous timbers. The fibers are moderately thick walled and parallel to the vessels. Across the grain the medullary rays run from the bark to the pith and, in birch, show a homogeneous arrangement. According to the definition of the IAWA, rays are called *homogeneous* when all cells are procumbend (Fig. 26, left). On the other hand, cell elements that are standing or

upright occur in certain rays. These cells occur mainly on both marginal sides of the ray and are characteristic of *heterogeneous* rays (Fig. 26, right). The differences between homogeneous and heterogeneous rays can best be seen by comparing the radial section with the tangential section.

*Tangential section.* The tangential section shows very clearly the oblique joining of the vessel members. The perforation plates (Fig. 27) and their bars are cross-sectioned, and the bars occur in microscopic view as small knots. The long walls of the pores are punctuated by a great number of very small pits that are arranged in alternate rows. It can be seen in the cross section, and much more clearly in the tangential section, that the rays (Fig. 27) differ in their size. Rays of only one cell row and others that are up to three and four cell rows wide can be seen. They are spindle shaped and are usually filled with a black material. Their height also differs but only within a normal range; no extremely long or extremely short rays can be seen. As in most of our European timbers, the rays in birch are constructed rather simply. Sheath cells, tile cells, different canals, oil, and cristal cells cannot be detected in *Betula*, but this enumeration shows the different possibilities of ray organization (*3*).

### References and Notes

1. The photomicrographs were made in our laboratory for electron microscopy. I am indebted to A. Frey-Wyssling and K. Mühlethaler for their kindness and courtesy in permitting me the use of this equipment, without which these investigations would have been impossible.
2. J. W. Bailey, Chron. Bot. 15 (1954).
3. I cannot give a comparative anatomical study here nor go further into structural details, but I refer all interested readers to the complete studies of E. W. J. Phillips, *Identification of Softwoods* (H.M. Stationery Office, London, 1948), and H. P. Brown, A. J. Panshin, C. C. Forsaith, *Textbook of Wood Technology* (McGraw-Hill, New York, 1949).

*A trained, and mind you I say trained, scientific researcher thinks only of the object he has before him, not of any ideology, not of himself, not of his publicity, not of what anybody thinks of him or his associates, not of another job—but only of one thing—what do the facts justify? How helpful it would be if we could have more trained minds to see errors, to pass judgment and guide action before it is too late.*—BERNARD M. BARUCH.

# Modern Science and Refutation of the Paradoxes of Zeno

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ABOUT 2500 years ago, a Greek named Zeno of Elea confounded his contemporaries by a series of startling arguments. These were designed to show that the science of geometry is beset by a paradox and that any attempt to provide a mathematical description of motion becomes ensnared in contradictions. So seminal was the scientific challenge bequeathed to posterity by Zeno's polemic that the contemporary philosopher Bertrand Russell paid tribute to him (1), saying: "Zeno's arguments, in some form, have afforded grounds for almost all the theories of space and time and infinity which have been constructed from his day to our own."

Authorities disagree on the identity of the adversaries at which our searching Greek aimed his intellectual broadside. Disregarding entirely the question of historical authenticity, we shall consider a version of Zeno's paradoxes directly relevant to modern science. To my knowledge, the arguments that I shall offer in refutation of Zeno have not been given by previous writers. It will be best to examine (i) the geometric paradox, which impugns the consistency of the contemporary mathematician's conception of the relationship between a line and its points, and (ii) the paradoxes of motion by which Zeno attempted to demonstrate the impossibility of motion.

## Geometric Paradox

In the geometric paradox, our philosopher asserts that it is self-contradictory to claim that a line segment consists of points, each having zero length (2). For if a line segment of, say, 2 centimeters actually does consist of points, then the total length of that segment should be computable by adding the individual lengths of its constituent points. But instead of yielding the required value of 2 centimeters, this computation unavoidably yields the paradoxical result of 0 centimeters, since a summation of zeros can issue in nothing other than zero. By the same token, Zeno argues that it is self-con-

tradictory to maintain that a positive time interval can consist of instants of zero duration. Among those who have taken up their cudgels on this issue, we find such diverse thinkers as Kant (3), P. du Bois-Reymond (4), William James (5), and P. W. Bridgman (6). Yet the very conception that Zeno and these writers would proscribe has become commonplace in contemporary science through the work of the German mathematician Georg Cantor (7, p. 275). It therefore behooves us to come to grips with this charge of absurdity.

Consider the computation by means of which Zeno deduced his paradoxical result. In order to add the lengths of all the points in an interval of 2 centimeters, we must first form a precise idea of how many points compose such an interval. We note immediately that the number of points here is not finite. But of what avail is the trite observation that it is infinite? To no avail, unless we succeed in giving a mathematically articulate characterization of the particular *kind* of infinite collection with which we are confronted. It was Cantor's achievement to provide precisely this characterization. And since it will give us the means by which to disprove the Zenonian allegation against geometry, we briefly pause to give a statement of its meaning.

Suppose that a very intelligent child who does not, however, know the names of numbers exceeding 10 is confronted with two bags of pennies, each containing more than 10 pennies, and is then asked to determine which of the two bags contains more pennies. By virtue of his limited knowledge of numbers, the child cannot make a separate count of the contents of either bag. But his intelligence will enable him to make the required determination nonetheless: he will pair off each coin in bag A with a specific coin in the other bag B. If he exhausts the coins in bag B and still has coins left over in bag A, then he will conclude that there are more pennies in bag A than in bag B. On the other hand, if the supply in B outlasts the supply in A,

he will know that the *B* collection is richer than the one in *A*. And if he comes out even, he will know, *without* having been able to make *separate* counts, that bag *A* contains the same number of pennies as bag *B*. By the same kind of reasoning, we know that, in a monogamous society, there are just as many husbands as wives, although we have not taken a census.

Cantor saw that this method of one-to-one pairing lends itself to the solution of the problem of comparing two *infinite* collections as to cardinality: two such collections are equinumerous, if there is at least one way of pairing off their members so as to secure for each member in either collection exactly one partner in the other. In the event that no such pairing can be achieved, the collection that is always left with some unpaired objects is the *larger* of the two. Now, Cantor was able to show (*7*, pp. 278–280) that the infinity of points in a unit line segment is larger in precisely this sense than the infinity of positive integers. Having called the latter infinity "denumerable," he then called the former "super-denumerable."

In the context of modern mathematics, Zeno is thus defying us to obtain a result differing from zero upon adding all the lengths of the super-denumerable infinity of points that compose a unit segment. This means that we are being asked to add as many zeros. To Zeno's mind, it was axiomatic that the result of any addition of zeros would be zero, regardless of the cardinality of the set of zeros to be added. But he could not anticipate that the addition of a *super*-denumerable infinity of numbers, be they zero or positive, presents a problem altogether different from adding *either* a finite sequence of numbers such as 3, 4, 7 *or* a *denumerable* infinity of numbers such as 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, . . . . Although arithmetic has evolved a definition of the "sum" of a *denumerable* infinity of numbers by a consistent generalization of the concept of finitary sum on the basis of the limit concept, this definition is utterly useless and irrelevant when the addition of a *super*-denumerable infinity of numbers is called for. Thus, the addition of the lengths of all the points composing a unit segment is a meaningless (undefined) operation in analytic geometry and hence cannot be used to compute a value for the total length of the segment. In particular, the deduction of Zeno's paradoxical result zero for the length of a unit segment is precluded by this arithmetical fact. And what holds for the unit segment also holds for a segment of 2 centimeters and for any other, for, *mirabile dictu*, Cantor demonstrated that no matter what their length, all line segments

contain the same super-denumerable infinity of points. Therefore, if the concept of super-denumerable infinity is itself free from contradictions, then Zeno's charge of inconsistency is false, both in regard to the decomposition of a line into mathematical points and with respect to the resolution of a time interval into instants of no duration (*8*).

Proponents of Zeno's view might still argue that this *arithmetical* rebuttal is unconvincing on purely geometric grounds, maintaining that if extension (space) is to be composed of elements, these must themselves be extended. Specifically, geometers like Veronese objected (*9*) to Cantor that in the array of points on the line, their extensions are all, as it were, "summed geometrically" before us. And from this geometric perspective, it is not cogent, in their view, to suppose that even a super-denumerable infinity of unextended points would be able to sustain a distance, especially since the Cantorean theory can claim arithmetical consistency here only because of the obscurities that obligingly surround the meaning of the arithmetic "sum" of a super-denumerable infinity of numbers.

Is this objection to Cantor conclusive? I think not. Whence does it derive its plausibility? It would seem that it achieves persuasiveness via a tacit appeal to a *pictorial* representation of the points of mathematical physics in which they are arrayed in the consecutive manner of beads on a string to form a line. But the properties that any such representation imaginatively attributes to points are not even allowed, let alone prescribed, by the formal postulates of geometric theory. The spuriousness of the difficulties adduced against the Cantorean conception of the line becomes apparent upon noting that not only the cardinality of its constituent points altogether eludes pictorialization but also their dense ordering: between any two points, there is an infinitude of others. Thus, in complete contrast to the discrete order of the beads on a string, *no* point is immediately adjacent to any other.

These considerations show that from a genuinely geometric point of view, a physical interpretation of the formal postulates of geometry cannot be obtained by the inevitably misleading pictorialization of *individual* points of the theory. Instead, we can provide a physical interpretation quite unencumbered by the intrusion of the irrelevancies of *visual* space, if we associate *not* the term *point* but the term *linear continuum of points* of our theory with an appropriate body in nature. By a point of this body we then mean nothing more or less than an element of it possessing the formal properties prescribed for points by the postulates

of geometry. And, on this interpretation, the ground is then cut from under the geometric *parti pris* against Cantor by the modern legatees of Zeno.

Apart from the *metrical* consistency of the modern conception of an interval as an aggregate of unextended points, mathematicians have succeeded during the current century in proving, by means of the *topological* theory of dimension, that there is also no contradiction in regarding the one-dimensional line as consisting of zero-dimensional points (*10*). This proof is not redundant with the foregoing analysis, since it turns out that the concepts of length and one-dimensionality are not at all the same.

In addition to refuting Zeno's geometric paradox, our analysis yields the following result: unless substantial modifications are made simultaneously throughout the body of analytic geometry, the proposal of some writers that we replace the Cantorean conception of the line as continuous by the postulate that it consists of only a *denumerable*, discontinuous infinity of points must be rejected on logical grounds of inconsistency alone (*11*). For the length or measure of a denumerable point set is zero, as can be seen upon denumerating any such set and then applying the familiar arithmetic definition of the sum of a denumerable sequence to the sequence of zeros representing the lengths of its members.

## Paradoxes of Motion

Among the four paradoxes with which Zeno sought to discredit the possibility of physical motion, only two are of relevance to contemporary mathematical physics. Their pertinence derives from that discipline's affirmation that the time variable ranges over the real numbers just as the space variable does. More particularly, it is the *denseness* of the ordering of these numbers, when they are arranged according to magnitude, that provides the point of application for Zeno's polemic. The claim that for any point on the path of a moving object, there is *no* next point, anymore than there is an immediately following or preceding instant for any instant during the motion, enables Zeno to ask incisively: In what sense can the events composing the motion be significantly said to succeed one another temporally, if they succeed one another densely rather than in the consecutive manner of a discrete sequence? This question takes the form of asking (i) how can a temporal process even begin, if, in order to survive the lapse of a positive time interval $T$, a body must first have endured through the passage

of an infinite series of subsidiary time intervals $T/2^n$ ($n = \ldots, 3, 2, 1$), which has *no first term* because the denseness postulate entails infinite divisibility, and (ii) how can a temporal process be completed in a finite time, if its completion requires the elapsing of an endless progression of temporal subintervals $T/2^n$ ($n = 1, 2, 3, \ldots$) in which there is *no last term* as a consequence of the denseness postulate?

The more familiar versions of these two queries are the "Dichotomy" paradox and the paradox of "Achilles and the Tortoise." In the former, whose argument was endorsed by A. N. Whitehead and P. Weiss (*12*), Zeno contends that the mathematical theory of motion entails the impossibility of the very process that it purports to describe, for if there is indeed no point *next* to the starting point on the path of a runner that he can occupy immediately after leaving the starting point, then an infinity of points and, hence, intervals inevitably always keep interposing themselves between the starting point and *any* other point to which the runner would move. And thus the motion is nipped in the bud, as it were. On the other hand, even if, *per impossibile*, the motion had begun, the paradox of Achilles shows that its completion in a finite time is quite unachievable. Having granted a head-start $d$ to the slow tortoise, which moves with velocity $v$, Achilles can never catch up with the turtle, despite his greater speed $V$: the fleet-footed warrior will *not* overtake the reptile after a time $d/(V-v)$, because there is no last term in the series of time intervals

$$\frac{d}{V} + v \, \frac{d}{V^2} + v^2 \, \frac{d}{V^3} + \ldots,$$

a series whose terms represent the successive times required by Achilles to traverse the successive distances separating him from the tortoise, beginning with the head-start $d$ of the tortoise.

According to a view that is as widespread as it is erroneous, Zeno's argument is no more than a mathematical anachronism. We are told that if he had only known, as we do today, that the arithmetic sum of an infinite convergent series is finite rather than infinite, then he would have recognized that he had merely posed a pseudo-problem. More particularly, the sum formula for a geometric series would have convinced him at once that the sum of the series considered in the Dichotomy is actually $T$ and that the series of times needed by Achilles to come abreast of the tortoise does add up to the finite value $d/(V-v)$. This retort is based on the fact that in modern mathematics, the arithmetic "sum" of an infinite con-

vergent series is *defined* as the limit of the sequence of its partial sums. An illustration will serve to introduce my contention that this rebuttal fallaciously attempts to settle a question of physical fact by invoking a *definition*.

Suppose that there were no limitations on the rapidity of human speech or thought, so that a man could recite the numbers 1, 2, 3, 4, . . . one by one, taking 1 minute to utter the first, ½ minute for the second, ¼ minute for the third, and continuing to require for each successive vocal act only half the time of its predecessor. The times taken to recite the infinite series of positive integers would therefore form the corresponding infinite series 1, 1/2, 1/4, 1/8, 1/16, . . . . Remembering that the series 1, 2, 3, 4, . . . has *no last term,* we now ask: Will it take our hypothetical man a finite or infinite amount of time to recite the totality of positive integers? Clearly, this question is one of physical fact. And no such question can ever be settled by having recourse to an *arbitrary* definition of what we shall mean by the "sum" of an infinite convergent series. Mathematically, it is entirely a matter of stipulation, as H. Hankel has explained (*13*), whether we define that sum to be finite in the customary manner or infinite. In any physical situation, it is therefore an open, empirical question which one of these two logically possible definitions is relevant.

It follows that the adoption of the first of these two definitions by the arithmetician cannot contain the answer to the telling question that Zeno raised when he asked, in effect: How can the description of motion resulting from the adoption of the customary limit definition of the "sum" of an infinite series in arithmetic be shown to be the physically true one in the face of the physical difficulties exhibited by the Dichotomy and Achilles paradoxes? To be sure, *if* it can be shown, independently of the meaning that arithmetical theory decrees for the term *sum*, that there are no *physical* reasons after all that would preclude the inception and completion of the motion in a *finite* time, then, of course, the familiar summation procedure used in arithmetic will tell us the length of the required time interval. It will not do to object at this point by saying that a mere glance at a unit line segment establishes that the customary limit definition of "sum" is the physically relevant one, as is seen upon subdividing the unit segment into an infinite sequence of diminishing subintervals ½, ¼, ⅛, . . . , all of which must be contained in the original unit segment. This objection offers a false analogy between a static whole already present in its entirety and subjected to divi-

sion merely in retrospect, on the one hand, and, on the other, an as yet unbegun or uncompleted temporal process, whose very inception or consummation is first at issue, as we saw in the case of the recital of the set of positive integers.

What is required in order to refute Zeno's objections to the mathematical theory of motion is a proof that neither the denseness of the ordering of the constituent events of the motion nor such features of this process as are entailed by this denseness property constitute obstacles to its inception and consummation.

To lay the groundwork for this proof, we ask: What is the basis for the view that the very meaning of temporal succession involves that events follow upon one another *seriatim,* like the consecutive beats of the heart, and not densely? The answer can be none other than that this feeling derives from a tacit appeal to the properties of the time flow experienced intuitively in human consciousness. Since each act of thought takes a positive amount of time rather than a mere instant of zero duration, it is inevitable that upon analyzing the stream of consciousness into a succession of constituent moments or "nows," these elements are experienced as occurring in a discrete sequence. No wonder therefore that on such an intuitively grounded meaning of temporal succession, there is an ever-present feeling that if *physical* events are to succeed one another in time, their order of occurrence must also be discrete, if it is to be a temporal order at all. It follows that refutation of Zeno will be at hand, if the *psychological* criterion of temporal sequence can be supplanted by a *strictly physical* criterion whose definition of "event B is later than event A" does *not* entail a discrete temporal order but allows a dense order instead!

Fortunately, the definition of time order and direction made possible by a careful interpretation of the second law of thermodynamics provides a criterion with precisely these required properties. Subject to a qualification to be mentioned presently, this definition can be stated as follows: Of two entropy states of a closed nonequilibrium system, the state of higher entropy will be *called* the temporally *later* state. And we see now that the entropies of a closed system, whose values are given by *real numbers,* can entirely intelligibly characterize a set of physical states that form a linear Cantorean continuum and are thereby densely ordered with respect to the relation "later than."

The qualification to be mentioned is made necessary by the fact that the so-called "periodicity" and "reversibility" objections of statistical mechanics have shown that the entropy of a single closed sys-

tem does not increase monotonically with time. A viable definition of time order on the basis of the second law of thermodynamics must therefore utilize a more complicated definition that makes reference to the statistical behavior of a *class* of closed systems rather than merely to a single such system. For the numerous relevant details, I must refer the reader to other publications (*14*), where he will also find my reply to the operational critique of the entropic definition of time order offered by P. W. Bridgman (*15*).

Our analysis has shown that we are absolved from the necessity of answering "how" a succession of events can occur by exhibiting a discrete sequence of occurrence. Upon freeing ourselves from the limitations of the psychological criterion of time order by means of the constructive elaboration of an alternative, autonomous physical criterion, it becomes clear that the dense temporal ordering of the constituent point-events of a motion is no obstacle whatever to either its inception or its completion in a finite time. And thus it is seen to be entirely unwarranted to ask "how" the motion can occur despite the dense temporal order, or what the runner does immediately after leaving his point of departure.

Given that it is established now that the entire dense set of events constituting the motion can occur, we can, of course, subdivide it mathematically into various kinds of spatial and temporal subintervals. Thus, the distance traversed can be subdivided into an arbitrarily large finite number of *equal* subintervals. By the same token, the dense ordering allows us to subdivide the motion mathematically into a regression of decreasing time or space subintervals, having no *first* subinterval, as in the case considered in the Dichotomy. Or, we can mathematically effect a subdivision into a progression of decreasing subintervals, which has no *last* subinterval, as is illustrated by the mathematical decomposition of the motion of Achilles. But it would be a grievous error to infer that the individual terms of these infinite series denote *physically distinct* steps into which the motion has been chopped up, and which the runner executes *staccato* rather than *legato,* as musicians would say. For no infinite set of *distinct*, consecutively ordered operations would constitute a physical process that is temporally continuous in the mathematical sense, as the runner's motion is assumed to be. And any such *discontinuous* physical process would indeed defy completion in a finite time: the execution of the geometric progression of physically distinct acts of reciting the positive integers in the manner described earlier would take forever (*16*).

Zeno can therefore not embarrass us by his purely mathematical decompositions of the motion into a discrete denumerable infinity of subintervals. Neither can he create difficulties by pointing out that if we consider the series of individual point-events that divide one subinterval from the next in the Achilles paradox, instead of considering these subintervals themselves, then indeed we *are* confronted with an *unending* progression of physically distinct events, all of which must have elapsed by the time the motion is completed. For by Zeno's own standards, as enunciated in connection with the geometric paradox of extension, no less than by the results of modern measure theory, the total time required for the occurrence of that discrete denumerable sequence of *point*-events is *zero*. Accordingly, this sequence, although unending, can hardly preclude the occurrence of the terminal event of the motion after a finite time.

## Quantum Theory

What is the essential bearing of the quantum theory on the argument offered here? The hypothesis of the atomicity of change has taken the form of postulating that there are minimal processes in nature in the sense that no changes occur and remain below certain spatial and temporal minima. The proposed minimal displacement or length, the "hodon," is of the order of $10^{-13}$ centimeter, the diameter of an electron. And the minimal duration, or "chronon," is of the order of $10^{-23}$ second, the time required by electromagnetic disturbances, the fastest in nature, to traverse a hodon. Thus, space, time, and change are quantized in the same contingent physical sense in which masses are quantized by the existence of an elementary particle of minimum mass. Being extensive magnitudes, whose values are given by real numbers, "atoms" of space or time presuppose logically all the constituent parts of which they can be regarded to be the sum. In *each* of the finite number of hodons that the runner traverses, he goes through a continuum and hence a dense infinity of points and instants! The "atomicity" of physical processes affirmed by quantum theory is therefore anchored in a mathematical continuum. And the results of that theory do not render our refutation of Zeno either superfluous or invalid.

In regard to theories of space or time quantization that are not grounded in a mathematical continuum but are thoroughgoingly atomistic, it will suffice to cite the following perceptive comment by H. Weyl (*17*): "So far, the atomistic theory of space has always remained mere speculation and has never achieved sufficient contact with reality. How should one understand the metric relations

in space on the basis of this idea? If a square is built up of miniature tiles, then there are as many tiles along the diagonal as there are along the side; thus the diagonal should be equal in length to the side."

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*A great deal of the joy of life consists in doing perfectly, or at least to the best of one's ability, everything which he attempts to do. There is a sense of satisfaction, a pride in surveying such a work—a work which is rounded, full, exact, complete in all its parts—which the superficial man, who leaves his work in a slovenly, slipshod, half-finished condition, can never know. It is this conscientious completeness which turns work into art. The smallest thing, well done, becomes artistic.*—WILLIAM MATHEWS.

# Radiocarbon Dating in the Light of Stratigraphy and Weathering Processes

## CHARLES B. HUNT

*Mr. Hunt, who received his training at Colgate and Yale universities, served with the U.S. Geological Survey from 1930 until 1953, when he became executive director of the American Geological Institute. During World War II he was in charge of the Military Geology Unit, a corps of geologists, hydrologists, and soil scientists who provided terrain intelligence for the Corps of Engineers. After the war, while serving as Regional Geologist in Salt Lake City, Utah, he became interested in the interrelationships of geology, soils, and archeology. In 1948, as chief of the General Geology Branch, he supervised the survey's Pleistocene and Recent investigations.*

THE published radiocarbon dates are numerous. When considered stratigraphically, they are sufficiently scattered and erratic to provide some determinations that will support almost any proposed correlation. Some of the radiocarbon dates, for example, support the old geologic estimates that the date of the last Wisconsin glaciation was of the order of 20,000 years ago, but another and larger group indicates that the last glacial maximum occurred only 10,000 or so years ago. Which should be accepted?

In order that a technique or discipline may be useful in scientific work, its limits must be known and understood, but the limits of usefulness of the radiocarbon age determinations are not yet known or understood. No one seriously proposes that all the determined dates are without error, but we do not know how many of them are in error—25 percent? 50 percent? 75 percent? And we do not know which dates are in error, or by what amounts, or why.

This paper *(1)* attempts to review the stratigraphy of the late Pleistocene and Recent deposits sufficiently to illustrate some of the principles that are involved. It attempts, further, to review a few of the conflicts between the known stratigraphy and radiocarbon dates and some aspects of the problems involved in the weathering or preservation of specimens for carbon-14 analysis.

## Late Pleistocene and Recent Stratigraphy

The span of time to which radiocarbon dates can contribute information is about 30,000 years and embraces the late Pleistocene and Recent ages. Our knowledge of this stratigraphy has been slow in developing because, until recently, there has

been little attempt to apply to these young deposits the same principles of stratigraphic usage that have been applied to the remainder of the geologic section. Actually, unconsolidated deposits involve the same principles of stratigraphy as do the bedrock formations. The deposits can be separated into mappable lithologic units—groups, formations, and members—based on superposition; the contacts between the formations can be traced laterally and the lithologies can be found to change laterally and vertically because of differences in regimen of sedimentation. Moreover, there is a substantial amount of paleontology and archeology on which to base a stratigraphic classification of late Pleistocene and Recent deposits (Table 1).

Vertebrate paleontology helps separate Pleistocene from Recent deposits and helps separate historic from prehistoric Recent deposits. Moreover, in some areas where vertebrate remains are abundant, such as the Great Plains, it is possible to recognize facies differences; for example, in the Denver Basin the mammoth remains are most numerous in the floodplain deposits, whereas camel remains are most abundant in the loessal deposits on the uplands *(2)*. Invertebrate fossils and pollen have been used to considerable advantage too, for the abundance and composition of the floras and freshwater invertebrate faunas changed and the centers of population shifted in response to the fluctuations in ground drainage and other conditions during the late Pleistocene and Recent ages.

Archeology supplements paleontology in helping to decipher late Quaternary stratigraphy. Archeological remains usually provide means for distinguishing between historic and prehistoric pottery cultures, and for distinguishing these from the earlier, pre-Christian, lithic cultures. At least two

prepottery lithic cultures can generally be distinguished—an early one associated with Pleistocene mammals that produced such distinctive projectile points as the Folsom, Sandia, and Gypsum Cave points, and one or more later lithic cultures, Recent in age, that produced stemmed and barbed projectile points. Only the uninitiated, however, would try to use a solitary projectile point or other artifact as an index fossil, for artifacts can be reworked into younger deposits, artificially or naturally, to the same degree that fossils are reworked.

Considering next the physical geology, we find a dozen or more independent lines of approach for determining the physical stratigraphy of the late Pleistocene and Recent deposits. Among the deposits that can be distinguished, and the principal sources of the specimens of radiocarbon that have been analyzed, are alluvial deposits, cave deposits, lake deposits, colluvial deposits, soils, and glacial deposits. This stratigraphy is summarized in Table 2.

*Alluvial deposits.* The alluvial deposits are best known in the western states, partly because they are better exposed there than they are in the east and partly because weathering in the humid east has been rapid enough to destroy most of the fossils that may have been in the deposits.

In most of the western states, the alluvial deposits can be divided into three or more formations separated by erosional unconformities. These formations differ from one another lithologically; their vertebrate and invertebrate faunas are differ-

ent; and they contain different archeological remains (3, p. 3). The deposits that contain the remains of Pleistocene mammals generally are thicker, more clayey, and more compact than the younger alluvial deposits that contain a modern fauna. In places these old alluvial deposits are correlative with glacial outwash. The Recent alluvium can be separated into older and younger deposits on the basis of superposition of beds and their archeological remains. The older is prepottery in age; the younger commonly contains pottery.

*Cave deposits.* The physical geology of deposits in limestone caves seems to be about the same throughout the world (4). The excavation of the caverns by running water represents a period when erosion by solution exceeded deposition. As the quantity of running water and the rate of erosion diminished, layers of gravel or beds of clay or ochre representing the insoluble residue from the limestone were deposited on the floor of the cave. As the flow of water further diminished to a mere drip from the roof, stalactites grew downward from the roof and stalagmites were deposited on the clay or ochre. Finally, as seepage ceased altogether, the stalagmites ceased to grow and became buried by layers of dust.

Rather generally throughout the world, the remains of Pleistocene animals are found in and below the stalagmite layers. In many regions archeological remains are found with the remains of the extinct animals. Equally generally, the layers of dust above the stalagmites have yielded remains

Table 1. Late Pleistocene-Recent paleontology and archeology. The floral sequence is that for the northeastern states.

| Stages | Vertebrates | Freshwater invertebrates | Flora | Archeology |
|---|---|---|---|---|
| *Recent* | | | | |
| Historic drouth | Historic fauna | Scarce | | Historic occupations |
| Historic pluvial | | | Oak-hemlock | |
| 13th century drouth | | | Oak maximum | Pottery |
| Little Ice Age | Modern fauna | Moderate numbers and extent | Oak-hemlock | |
| Great drouth | | | | Prepottery lithic with modern fauna |
| | | Scarce | Pine | |
| *Pleistocene* | | | | |
| Wisconsin | | | | |
| Mankato | Pleistocene fauna | Abundant in numbers; extensive | Spruce-fir | Folsom, and others, with Pleistocene fauna |
| Cary | | | | |
| Peorian | | | | |
| Tazewell | | | | |
| Iowan | | | | |
| Sangamon | | | | |

of a modern fauna. In some places these layers yield a considerable stratigraphy of prepottery and pottery occupations.

*Lake deposits.* The deposits that accumulated in the large Pleistocene lakes, both in the west and in the Great Lakes region, contain the remains of Pleistocene mammals. Overlying the Pleistocene lake beds are Recent deposits of eolian sand, alluvium, or thin lake beds; these deposits contain the remains of a modern fauna. In the Basin and Range Province some of the Pleistocene lakes were 1000 feet deep. With the onset of the Recent, they became desiccated and today they contain salt lakes or playas. The volume of the Recent formations is trivial compared with that of the Pleistocene lake formations.

In the Lake Bonneville Basin numerous remains of Pleistocene animals have been found at levels more than 500 feet higher than Great Salt Lake. On the other hand, no articulated skeleton of the Pleistocene animals has been found below that level despite the fact that thousands of bones of modern animals have been collected by archeologists who have excavated in the many caves at all levels on the hills overlooking the lake (5, p. 29). It is difficult to escape the conclusion that the Pleistocene animals in this basin became exterminated, or their numbers reduced to the point of virtual extermination, when the water in Great Salt Lake stood about 500 feet higher than it does today. The deposits that formed at that stage intertongue with the youngest glacial outwash from the Wasatch Mountains.

*Colluvial deposits.* In most parts of the West a succession of colluvial deposits can be distinguished. These can be separated not only by their physical relations—that is, superposition—but also by their

archeological remains and by the desert varnish on the boulders on their surfaces.

*Soils.* Soil profiles are invaluable for recognizing, tracing, and reconstructing the history of late Quaternary deposits. Throughout the United States there can be recognized a soil that formed in pre-Wisconsin time (No. 1 in Table 2); it is a distinctive lithologic unit. In the West, it has been possible to distinguish a soil that formed during Wisconsin time, the so-called Brady soil (No. 2 in Table 2). This has not been identified in the east.

In the arid and semiarid parts of the country, soil development has been weak, and the Recent soils are too feeble to be useful stratigraphically except for distinguishing these deposits from older Pleistocene deposits. In the more humid areas however, a stratigraphy can be deciphered in some of the late Pleistocene and Recent soil profiles. The youngest soils (No. 4 in Table 2), more or less correlative with the pottery cultures, have a weakly developed leached zone—so slightly leached that fragments of shells that were in this zone are still preserved. Some podsolic soils with well-developed leached zones are prepottery in age, but are younger than some of the earlier lithic occupations—for example, the Leon soils in Florida (No. 3 in Table 2). In these soils leaching is strong enough to have removed practically all traces of shells that may have been in the deposits. No doubt, in time, it will be possible to distinguish soils that date from the last half of the Recent from those that date from latest Pleistocene time. In the northeastern states, normal gray podsols have developed since the waning of the last ice sheet; where these soils are fully developed they presumably represent most or all of the Recent.

*Glacial deposits.* The glacial deposits in the

Table 2. Late Pleistocene-Recent physical stratigraphy.

| Alluvial deposits | Cave deposits | Lake deposits | Colluvial deposits | Soils | | Glacial deposits |
| --- | --- | --- | --- | --- | --- | --- |
| | | | | West | East | |
| *Recent* | | | | | | |
| —Erosion | | | | | | Recession |
| Historic alluvium | | Desiccation and | Dissection | | 4 | Ramparts in cirques |
| —Erosion | Dust | change to sub- | | | | Recession |
| Prepottery alluvium, modern fauna | | aerial conditions | Prepottery colluvial aprons | 3 | 3 | Moraine |
| Dunes, erosion | | | Dissection | | | Recession |
| | ———Stalagmites——— | | | | | |
| *Pleistocene* | | | | | | |
| Alluvium with Pleistocene fauna | Ochre, other insolubles | Thick lake deposits like Provo and older Lake Bonneville formations | Colluvial aprons with mudflow, landslides, and springs | 2 | 2? | Wisconsin moraines and periglacial boulder fields |
| | | | | 1 | 1 | Sangamon residuum |

mountains of the western states record a climatic history quite like that recorded by the alluvial, cave, lacustrine, and colluvial deposits. The last major glaciation in the mountains seems to have been followed by a period in which most or all of the glacial ice was melted. The outwash from these glaciers can be traced into the alluvial deposits or lake deposits that contain remains of Pleistocene animals and, locally, Folsom and related artifacts. Similarly, in the Middle West and East, fossils rarely occur in the morainic deposits, but they are found in the outwash from those deposits.

Subsequently, there were comparatively minor advances of the mountain glaciers that are analogous to and probably correlative with the development of small lakes in the Great Basin and alluviation in the valleys (6).

*Other deposits.* Other deposits that are important in the stratigraphy of the late Pleistocene and Recent include eolian deposits, which occur both as dune sand and as loessal silt, and littoral deposits along the coasts. The dune sand occurs along the unconformities between the alluvial or lacustrine deposits (7). The loessal silt is Pleistocene in age and forms extensive blankets on the uplands leeward from valleys that were aggraded with glacial outwash.

### Comparisons between Stratigraphy and Radiocarbon Dates

A review of the published radiocarbon dates reveals four kinds of inconsistencies: (i) reversed dates in individual stratigraphic sections—for example, Annis shell mound and Bat cave; (ii) discordant dates for different samples from the same layer—for example, Belt Cave, Iran, Barbeau Creek rock shelter, Ill., and Leonard rock shelter, Nev.; (iii) discordant dates for stratigraphic units that can be related or correlated regionally—for example, Two Creeks and Danger Cave; and (iv) dates for isolated samples that conflict with other local evidence such as dendrochronology—for example, Red Rock Valley, Ariz.

On the other hand, there is considerable consistency among samples from within a region or among samples from stratigraphic suites. Moreover, the dates determined for samples obtained from ancient tombs have been confirmed by the historic record. The dates from the pyramids were excellent and a personal experience has made me quite conscious of the usefulness of samples from dry environments. A granary in a dry cave in southeastern Utah was dated by Alice Hunt as Pueblo II, A.D. 900–1100 (8). From the granary wall was collected a piece of wood that had been

encased in adobe, and Kulp determined its age and dated it A.D. 1000 (9). Such examples seem to indicate that

(i) the principle of the method is sound; (ii) the basic laboratory problems have been overcome; (iii) samples preserved under conditions simulating those of a sealed test tube give satisfactory results. In addition, if we look only at samples taken from dry environments, we find that they are reasonably consistent among themselves and that they indicate that the old geologic estimates were pretty good. Looking only at these samples suggests that the last glacial maximum was roughly 20,000 years ago. The dates obtained from this suite of samples, which is symbolized by the Danger Cave set, are supported by the dates obtained from many other samples that have been collected from similarly dry environments. Charcoal in a hearth under one of the Pleistocene lake deposits at Tule Springs, Nev., is more than 24,000 years old. The pre-stalagmite layer at New Cave, N. M., is more than 18,000 years old. The pre-stalagmite occupation layer at Sandia Cave is more than 20,000 years old.

The geological setting of Danger Cave is illustrated in Fig. 1. The cave, 50 feet above Great Salt Lake and 550 feet below the Provo shoreline, has not been flooded since it was first occupied, and this first occupation has been dated by Jennings at 11,500 years ago (10). The Provo formation intertongues with the youngest glacial outwash from the Wasatch Mountains, and Pleistocene fossils have not been found in any of the younger lake deposits. Assuredly the Provo formation is correlative with the last glacial maximum, and the earliest occupation at Danger Cave occurred well along in the Recent.

A recent attempt to correlate four stages of the Wisconsin Lake Bonneville as Nebraskan, Kansan, Illinoian, and Wisconsin stages (11) simply does
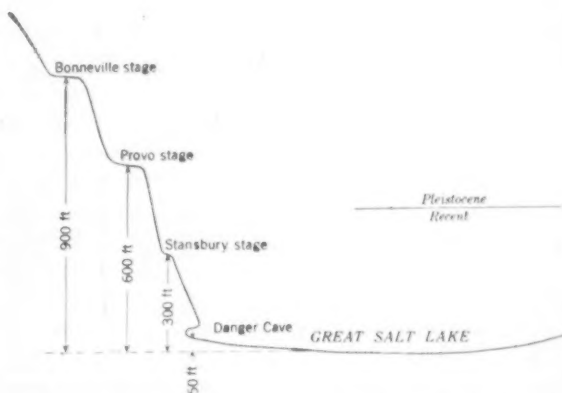


Fig. 1. Relationship of Danger Cave to lake stages.

not stand elementary analysis. It ignores 750 feet of Pleistocene deposits, including several thick lake formations, that underlie the Lake Bonneville group (5, pp. 14–16). It requires that the pre-Lake Bonneville moraines at the mouths of the canyons be Pliocene. It requires extermination of the Pleistocene animals in Sangamon time. But even this extreme correlation leaves Danger Cave as post-Pleistocene.

Although the dates from Danger Cave and other dry-region sites are consistent among themselves and support the old geologic estimates, the dates given for samples from wet environments, mostly humid regions, also are consistent among themselves and indicate a time scale only half as long. These determinations from humid regions are numerous and it is possible to select a long or short timetable depending on one's choice of the available numbers. Table 3 illustrates four quite different stratigraphic arrangements of radiocarbon age determinations.

This table does not, by any means, incorporate the extremes of the dates that have been published. The Farmdale at Wedron, Illinois, for example, has been dated at less than 14,000 years. Cary dates range from less than 8000 to more than 31,000 years. The majority of the dates are in the ranges shown in column 2 in Table 3, and this has become the fashionable chronology. This choice, however, constitutes a strictly numerical solution to a natural science problem, and as long as we do not know the reasons for the discrepancies in the dates we have no basis for preferring those that approximate the mean or average. Depending on the reasons for

Table 3. Four late Pleistocene and Recent stratigraphic sections, based on radiocarbon dates.*

| Section | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Recent | 6,400 | 7,800 | 10,900 | 11,500 |
| Mankato | 8,200 | 10,700 | 12,100 | |
| | | | | 18,000 to |
| Cary-Mankato | | 11,400 | | 24,000 |
| Cary | 11,000 | 13,600 | 18,500 | 31,000 |
| Brady | 14,000 | 16,400 | | |
| Tazewell | | 18,000 | 21,400 | 34,000 |
| Iowan-Tazewell | 16,400 | 20,700 | | |
| Iowan | | | | 34,000 |
| Farmdale | | 22,900 | 25,100 | |

* Localities and numbers of the samples are as follows, reading down. Column 1: Cochrane, Ontario (W-136); Toleston, Ill. (C-674); Dyer, Ind. (C-801); Story County, Iowa (C-664); Clear Creek, Iowa (20). Column 2: Barbeau Creek rock shelter (C-904); Kimberly, Wis. (C-630) [or Lake Aggasiz, (C-497) 11,300 years]; Two Creeks, Wis.; Cleveland, Ohio (W-33); Clear Creek, Iowa (C-528); Chillicothe, Ohio (W-91); Dayton, Ohio (W-37); Farm Creek, Ill. (W-68). Column 3: Barbeau Creek rock shelter (C-904); Bonfils terrace (C-385) [or Skunk River, Iowa (C-596) 12,000 years]; Dyer, Ind. (C-871); Newark, Ohio (W-88); Farm Creek, Ill. (W-69). Column 4: Danger Cave, Utah (C-609); New Cave, N. M. (C-898), Sandia Cave, N. M., and Tule Springs, Nev. (C-914); Redwood Falls, Minn. (W-99) (Cary or Mankato); Lake Bloomington, Ill. (W-67); L. Horberg, cited in communication.

the discrepancies, the significant numbers might be the largest ones, or the least.

It should be noted that most of the samples collected from dry environments indicate a chronology like that in column 4 of the table. Most of the dates from humid regions indicate a chronology such as those shown in columns 1 to 3.

Now either the dry set or wet set can be right, but they cannot both be right unless the last glacial maximum, extermination of the Pleistocene mammals, first appearance of the modern fauna, first appearance of early man in the United States, and the soil weathering that can be correlated with these events, occurred 10,000 or so years earlier in the west than it did in the east. Indeed, if we accept the radiocarbon dates shown in Column 2, it becomes necessary to conclude that the early-man sites in the west are pre-Wisconsin, and that the mammoth, camel, and other Pleistocene animals in the west became extinct before Wisconsin time, and that the Pleistocene Lakes became desiccated no later than early Wisconsin time.

There could, of course, be a 10,000-year difference in the age of these events in the direction of the ice advance or ice retreat, but the age range of a particular stage such as the ice maximum probably does not exceed scores or at most a few hundreds of years. Further, Horberg's recent work in Alberta suggests that the ice maxima in the Rocky Mountains were essentially synchronous with those on the Plains (12).

The dates from dry environments conflict with those from wet environments. Of the two sets I prefer the set from dry environments because these samples have been preserved under conditions most like those of the Egyptian tombs, which gave highly satisfactory age determinations. The samples from wet environments, in my opinion, are highly suspect because such environments favor contamination by younger, intrusive organic matter. Moreover, the degree of contamination would vary from region to region and from one locality to another within a region because of differences in environment. In addition, faith in the validity of age determinations based on samples from wet environments (moist soil) is not strengthened by what is known about the processes of weathering and plant decomposition (13, 14).

## Weathering and Decomposition of Plant Material

The zone of weathering annually has added to it fresh organic matter in the form of residue of leaves, stems, and roots of plants as well as dead insects, worms, and other animals. The bulk of this residue is deposited on the surface of the soil, but

certain parts of it—for example, the roots and carcasses of the soil micro- and macropopulation—are distributed throughout the soil profile. Furthermore, finely divided humus is washed from the surface into the cracks, old root channels, or burrows of rodents, worms, and insects. Shreds of leaves and grass blades are dragged into the soil by worms (15). Thus, in soils, fresh organic substances are continuously added to the remnants of the old organic matter—a fresh supply of carbon-14 is added annually to the upper layers of the soils, and the soil forming processes distribute this carbon-14 in soluble form to all layers of the soil.

The soil atmosphere, which has a higher carbon dioxide pressure than does the atmosphere above surface, probably contains nearly as much carbon-14 as the above-surface atmosphere because the soil process, consisting of downward percolating solutions containing organic matter, serves to replenish and to maintain the carbon-14 content of the soil even under anaerobic conditions. Moreover, the soil solutions, whether gaseous or liquid, help sustain the microbial floras and faunas that feed on and cause decay of organic matter in the soil. Decomposition of organic matter in the soil is largely a biochemical process. Inorganic oxidation of organic carbon plays a very minor role.

Fresh organic residues consist largely of various carbohydrates—starches, sugars, celluloses, and lignins—proteins, fats, resins, and waxes. These substances differ from one another in stability against decomposition. Proteins (protoplasm) are the least resistant and the first to decompose. They are followed by the carbohydrates in the order of starches, celluloses, and lignins. The protective substances such as chitin and the waste products such as the resins, waxes, and gums are the most resistant to decay and difficult to break down (16). Such differential susceptibility to decay and contamination might explain why hazelnuts from a Danish site appear to be 1300 years older than charcoal from the same site (17, p. 112, samples C-433 and C-434).

When wood decomposes, the cell walls become thinner because the cellulose and hemicellulose are removed (13). Finally, only a thin wall of lignin remains, and this wall becomes permeated with a dark brown stain of humic compounds (18). This stain would not develop, and the cellulose and hemicellulose would be preserved if the specimen were protected against outside influences—that is, preserved in a sealed test-tube condition. But in a weathering zone, bacteria and/or fungi invade the specimen and attack the cellulose and hemicellulose in a medium of soil solution and soil atmosphere containing younger carbon-14. The

greater part of the specimen, perhaps 90 percent by weight, is removed in solution. The brown stain in the lignin walls evidently is the product of the metabolism of the microorganisms. Such waste products are more resistant to decomposition than the lignin and may therefore become a high percentage of the residue. In fact, removal of the interstitial lignin could lead to pseudomorphous replacement of the entire wall by reworked carbon and by younger, introduced carbon.

The question whether carbon can replace carbon has led to some confusion because the term *replace* may be used in different ways. One meaning refers to replacement of an atom within a molecule, and in this restricted sense there may be little or no replacement of carbon by carbon. But the term also refers to the deposition of any substance, regardless of composition, in the space formerly occupied by another, and in this broad sense, of course, there are many ways—physical, chemical, and biological—by which younger carbon compounds can replace parts or all of older ones.

The rates of chemical processes depend upon the temperature. In general, a rise of 10°C doubles the rate of organic reactions. In the northern United States, therefore, the rate of chemical reactions in the soil may be only half or a third of the rate in the southern United States. The optimal temperature of biochemical activity is in the neighborhood of 35°C. The lower the temperature, the less efficient the process. At the freezing point virtually all biochemical processes come to a standstill, as is shown by the preservation of the carcasses of prehistoric animals in the perennially frozen soils. This is also why, in cool and cold climates, plant debris does not decompose as fast as it forms and, hence, accumulates to form peat, whereas in the hot and humid tropics most soils are practically free of organic matter in spite of enormous masses of vegetable material built up by photosynthesis.

Metabolism of soil micropopulation is accompanied by formation of various by-products that are toxic to their producers. If these toxins are not removed, for example, in stagnant water, swamps, or waterlogged soils, they accumulate to the point that they inhibit microbial activity and finally check it altogether. This is another essential factor of peat formation, a sort of natural self-sterilization of organic residues that prevents decomposition and makes possible their accumulation.

In swamps and marshes having highly toxic water, there is little decomposition, and even carbohydrates are preserved (19). In more aerated water the hemicellulose disappears, while in water that is well aerated the lignin is removed. At Upper

Linsley Pond in Connecticut, discrepancies were found in the radiocarbon dates of samples collected from the center and from the edge of the pond, and this was attributed to "mixing" (17, p. 114). Conceivably, however, the discrepancy is the result of greater microbial activity and contamination in the more aerated shore facies.

The availability of oxygen affects the rate of decomposition of organic matter (13) because the aerobic bacteria are more active than the anaerobic kinds. Peats accumulate because excessive moisture inhibits bacterial decay by excluding oxygen, but permits plant growth. This also may explain why organic matter accumulates in the waterlogged subsoil of a groundwater podsol.

Availability of oxygen—that is, whether the process is aerobic or anaerobic—temperature, $pH$ of the medium, and the disposal of the toxic byproducts are the principal factors that control the microbial activity in organic residue and determine the state of soil organic matter, especially the relative concentration of carbon-14. Each of these factors in its own way affects the changes in the $C^{14}/C^{12}$ ratio. Some of them might inhibit the contamination of old organic matter in one environment but enhance it in another.

This discussion has emphasized the potential contamination that could be caused by microorganisms. It is not intended to minimize the fact that intrusive macroorganisms, when they are carbonized, also become practically indistinguishable from the host material.

A buried soil or any buried organic material must be adequately sterilized and protected from contamination to be of any value for the age determination of the relics. If this condition is not fulfilled, we must find some criteria for an accurate evaluation of inevitable errors in our radiocarbon date determinations. Otherwise we never can be sure that our dates are not "too young."

Contamination of buried plant material by living macro- and microorganisms and/or by soil solutions containing humic compounds, whether in true solution or suspension, would be a function of the environment, and fair consistency between samples collected from within a region or from a stratigraphically arranged suite is to be expected. For example, in the zone of weathering, potential contamination decreases downward. The lower levels of a soil are less frequently wetted and contain less microbial population than do the upper levels. The difference in carbon-14 content of stratigraphically arranged suites of samples therefore may in part be the result of greater contamination of the upper samples. The consistency of dates obtained from stratigraphically arranged suites of samples may merely reflect the orderliness of the weathering profile.

On the other hand, one could expect gross differences in age determinations of samples collected from open sites in different regions.

Contamination would be least in regions where biochemical activity is retarded, such as in arid and semiarid soils and those of cold latitudes. It would be greatest in humid temperate regions where the environment favors biochemical activity and replenishment of carbon-14 in the subsoil, and it should be noted that a large proportion of the dates that many geologists suspect are "too young" —for example, Two Creeks—represent samples from humid, temperate regions.

Conversely, little contamination would be expected of samples from caves subject to only occasional wetting, and samples from this kind of environment include a high proportion of those that have yielded dates twice as old as those from humid regions.

Finally, samples obtained from environments where there has been no opportunity for contamination by younger organic matter, such as the samples from the Egyptian tombs, or the timbers that had been encased in adobe in dry shelters in the Pueblo country, have provided excellent dates that have been verified by history or by dendrochronology.

There does not appear to be any reason for questioning the reliability of radiocarbon age determinations of samples that have been preserved under conditions that preclude contamination by younger organic matter. But the determinations on samples that have been subject to contamination by soil solutions transporting soluble organic compounds and/or by bacterial and fungal attack must remain suspect until some way is found for determining whether this kind of contamination is or is not a significant factor. The answer will be difficult to obtain, but the question can be stated quite simply: how frequently can a piece of "dead" Pleistocene charcoal be soaked in a vinegar-like solution without reducing its radiocarbon age from Pleistocene to Recent?

### References and Notes

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In view of the systematic nature of science it might be thought possible that scientists could be organized as the subordinates of an authority centrally directing the completion of this system, each scientist being assigned the task of filling in one particular gap in the system. Tasks of this kind do in fact arise in the course of a process of surveying, but they are regarded as mere routine investigations, having little scientific value.

All real scientific discovery must show originality; it must expand the system of science in an unexpected way. The originality of an idea implies that the idea did not exist before it occurred to the person whose idea it was and could therefore not have been assigned to him by another person acting as his superior. This makes all scientific discovery an essentially independent task.—MICHAEL POLANYI, *Pure and Applied Science and Their Appropriate Forms of Organization* (Society for Freedom in Science, University Museum, Oxford, 1953).

# The Garter Snake

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THE harmless snakes in the United States outnumber the poisonous or harmful forms many times, in both number of species and number of individuals. Despite this fact, snakes are feared and avoided, and only a few try to acquire accurate knowledge of their nature. When one stops to inquire about the lives and habits of these animals, fear and indifference usually disappear.

Have you ever wondered how a snake courts its mate or how far it wanders, or how many snakes live in a particular area? The answers to these questions, and many others, involve special techniques and many hours of study and observation in the field.

The common garter snake, *Thamnophis sirtalis sirtalis* (Fig. 1), is probably the best known of our North American serpents. Its geographic range is east of the Mississippi River. However, there are many races and closely related species of garter snakes, whose lives are presumably quite similar, that have ranges extending across the prairies into the western mountains, to the Pacific, into Mexico (ancestral center of origin for garter snakes), and to the far northwest. What then is known about the life of this snake?

The active period of the common garter snake's life begins during the first warm days of spring that are accompanied by soaking rains. This new warmth seeping down into their subterranean winter seclusion stimulates some of them to emerge into the warm sunlight for a few hours each day. By the time April showers are in full swing, most hibernacula are abandoned and activity above ground is increasing with springtime fancies. This is the period of courtship and mating, the time of greatest activity in the annual cycle of the garter snake's life.

The average common garter snake is about 2 feet in length and lies close to the ground. Much of its habitat has vegetation that would prevent one snake sighting another unless it was very close by. Under these conditions, the male must seek out a female with which to mate. We have evidence that about 65 percent of the adult females are gravid each year, which may indicate that many do not have the opportunity to mate. Considering the handicap of short visual field with many obstructions, how is it that effective contact is made by the majority of the adults?

The following facts probably help to insure these contacts. Garter snake populations are much larger than would be suspected, exceeding 10 individuals per acre in suitable habitats. Hibernating snakes tend to congregate in favorable areas, and when they emerge in the spring ready to mate, they are already in close proximity. Of primary importance is the ability of the male to follow the trail of scent left by a female in the spring. I have watched males follow the exact path taken by a previously released female, making right-angle turns at the proper points.

The ritual that precedes mating begins when the searching male encounters a female. On the under side of the chin of the male are a number of small tubercles that it rubs a number of times fore and aft ("chinning") along the back of the female. At the same time the male brings its elongate body parallel to and alongside the female. If receptive, the female will slightly turn its cloacal region and thus permit the male to make entrance. (The males of some species of snake grasp the female behind the head with their jaws and maintain this position during coitus.) A female is often courted by more than one male at the same time but can mate with only one. The male has a longer tail than the female, and at its base there is a double copulatory organ (hemipenis), of which only one side is used in coitus. This intromittent structure has many recurved spines upon it, which, on hemipenal enlargement during copulation, become imbedded in the genital tract of the female. This prevents separation until mating is complete, and often a female may crawl away during the act, dragging its mate along.

Not all garter snakes mate in the spring, and courtship and coitus have frequently been observed in the autumn. Because ovulation does not occur until spring, to achieve a successful fertilization, the sperm received by fall-mated females must remain viable over the winter months. Experiments have shown that this happens, and recent evidence indicates that the uterine walls are especially adapted for retaining viable sperm. Haines has shown that in *Leptodeira* (cat-eyed snake) of Central America sperm may remain viable in the female for 5 years. You may ask why this occurs. In the garter snake, and presumably also in other forms, sperm storage increases the potential of successful mating. The fact, already mentioned, that many females do not find mates every spring is indicated by the finding of many non-gravid females in early summer. The female that had retained viable sperm over winter could have young without a new mating.

During the summer, gravid females become less active than the males, and many seek seclusion in groups of from two to five or more until late summer or early autumn when the young are born alive. Although many snakes lay eggs, the garter snakes, water snakes, rattlesnakes, and some others retain the eggs, which do not have a hard shell, and the embroyos develop in the uterine tubes. When they are "ready to hatch," the embryos break out of the egg membranes as they are born. Within a few minutes to a few hours after birth, the newborn garter snake sheds its "skin," a very filmy epidermal covering. The litter size of the common garter snake may vary directly with the size of the female, the average litter being about 18, while the largest litter recorded, from a very large female (43½ inches), was 80 young.

Newborn garter snakes are completely independent and begin to scatter soon after birth, perhaps never again to come in contact with their mother. These juveniles look and behave like miniatures of their parents—tongues flicker and eyes are alert. Snakes are always born with their eyes open and, since they lack eyelids, the eyes never close throughout their lives. A transparent spectacle scale over each eye is replaced with each molt of the skin.

Young garter snakes grow very rapidly and double their body length in the first year. As they grow older the proportional rate of increase slows down, and large individuals show very little annual growth increment, although they never stop growing. The growth rate of the female is slightly faster than that of the male, with the result that adult females are longer than adult males of the same age, in spite of the male's proportionately longer tail. The largest garter snakes are almost always

females. Probably many live beyond 10 years of age, and a 20-year-old garter snake has been recorded.

Snakes are unique creatures for those who wish to study their food habits. With a little experience, one can learn to force them to regurgitate their last meal by working the fingers from the tail toward the front along the belly. In this manner, a snake is relieved of its recent meal, which is then analyzed, and the animal, being unharmed, goes in search of more food. Thus, one snake may offer more than one food record, giving evidence for or against individual preferences for particular available foods.

Definite food preferences are not indicated for the common garter snake, since it eats what is most available or obtainable. Preferences that do appear can usually be explained for other reasons. Juvenile individuals will take small species of frogs and the smaller forms of larger frogs, while the adult snakes eat the larger frogs in preference to the smaller forms. The juvenile individual, of course, is unable to swallow the larger frogs, even though they are present. Throughout the active part of the year the species eaten will vary with the seasonal activity of the prey. Frogs and other types of prey that are most active in the spring will dominate the food records for this period, and the same holds for the other seasons.

The diet of the common garter snake is varied, although certain types dominate. Earthworms form the major type of food taken, followed by frogs, toads, salamanders, and fish; leeches, small mammals, birds, some caterpillars, and perhaps other insects are of minor importance. If toads are very abundant in one particular part of its geographic range, they may form a major source of
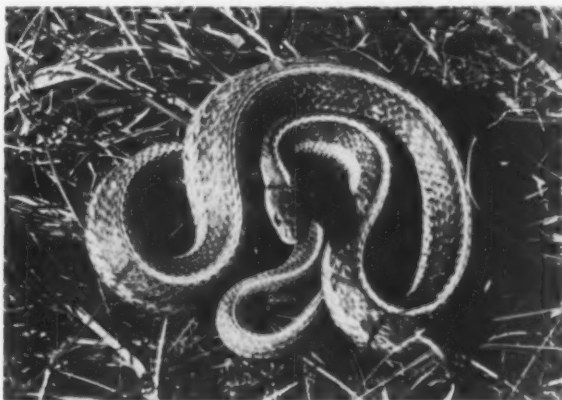


Fig. 1. The common garter snake is probably the best known of our North American snakes. By using special techniques, many new facts have been disclosed about its movements and abundance.

food, or under certain conditions, fish may be the predominant item of diet.

I have frequently watched one of these snakes crawling along the edge of a pond searching for food. It is a rather inefficient stalker, time after time missing a frog that it is chasing, often passing close to other frogs without realizing their presence.

Its forked tongue is an organ used to aid in smelling. When active, the snake darts its tongue quickly out, the waving tips picking up small particles. The tongue is then retracted, and the tips carry the particles to a special sensory area for smell on the roof of the mouth (Jacobson's organ). The snake is very dependent on this sense for interpreting possible food.

Anyone who has spent much time searching for garter snakes is aware that they are more active during certain times of the year, and also that certain environments have larger numbers of snakes. The habitat preference of the common garter snake is very broad: woods, fields, swamps, city lots, and back yards. Generally, however, the garter snake is more abundant where these are in the vicinity of a pond, stream, or some other body of fresh water. They will climb bushes and small trees (especially in hot weather when the temperature in the bushes is lower), move into the center of a marsh, swim across a small lake, go underground into rodent burrow or other types of burrows, hide in logs, under trash, or in a wood pile.

Questions that are often asked are: How old is this snake? Where did it come from? How many snakes are there in this area? Is this the same snake that I saw here last month?

By using a method of marking snakes so that each individual can be recognized when it is recaptured at a later date, we are now beginning to find the answers to these questions. This marking technique, developed by the late Frank N. Blanchard, involves clipping the two rows of scales beneath the tail in various combinations (Fig. 2).

Evidence that I gathered from more than 1500 marked individual garter snakes over a number of

years (in Michigan) indicated that these animals are limited in their movements; that is, they do not wander at random but confine their activities to areas of about 2 to 3 acres (Fig. 3). The activity ranges of different individuals overlapped and frequently two snakes had almost the same activity range. In a favorable habitat, the activity ranges were more or less evenly distributed over the entire area.

In one 48-acre area, the population was calculated to be 432 common garter snakes, or 10 snakes per acre. Since some parts of the area were unfavorable, the density would be greater in the preferred habitats. There were more than 500 other snakes, mostly two other species of garter snakes, in the area. Adding these to the total snake population would make a density of approximately 20 snakes per acre, or perhaps much greater in certain favorable areas. One does not usually see snakes in this abundance. As a matter of fact, an experienced observer searching this area for an entire day would probably be fortunate to find 20 or 30 snakes. Most of the population either would be inactive and well hidden or would find cover before being noticed.

For the vast majority of garter snakes, activity begins to dwindle toward early October, and by the time frosts arrive they have gone into hibernation. However, a few individuals may be seen on warm autumn days basking in the sunshine for short periods.

The hibernacula vary greatly, depending upon what is available. It is necessary for the garter snake to reach some region that will be out of the zone of prolonged freezing temperatures. A related garter snake has been known to survive for as long as 28 days (18 inches beneath the ground) at subfreezing temperatures. Many situations are used as winter sanctuaries; some that I have noted are rodent tunnels, cavities beneath rocks, large ant mounds, and crayfish burrows. In the crayfish burrow, one snake was 2 feet beneath the level of the water that flooded the tunnel. These snakes will probably use as hibernacula any subterranean cavity in which they can go deep enough to escape prolonged freezing temperatures. Many do not find such structures and become "winter kills."

The hibernation activities of snakes that used a large ant mound were watched over a period of 3 years. During the second spring, a large cone-shaped cage was placed over the ant mound, so that a record could be made of animals emerging. During this spring, 75 snakes (six different species), a frog, and a salamander emerged. The period of emergence extended from 27 March to 31 May, reaching a peak in early April. All the snakes that used this anthill were either the young



Fig. 2. On the underside of a garter snake's tail there is a double row of alternating scales. Areas from which scales are removed by clipping into the underlying muscle show a readily recognizable scar on healing. By numbering the scales posterior from the anus and by clipping differently numbered combinations of scales, one can recognize individual snakes over long periods of time. The snake shown here has been marked on the right, 4, 11, 16.
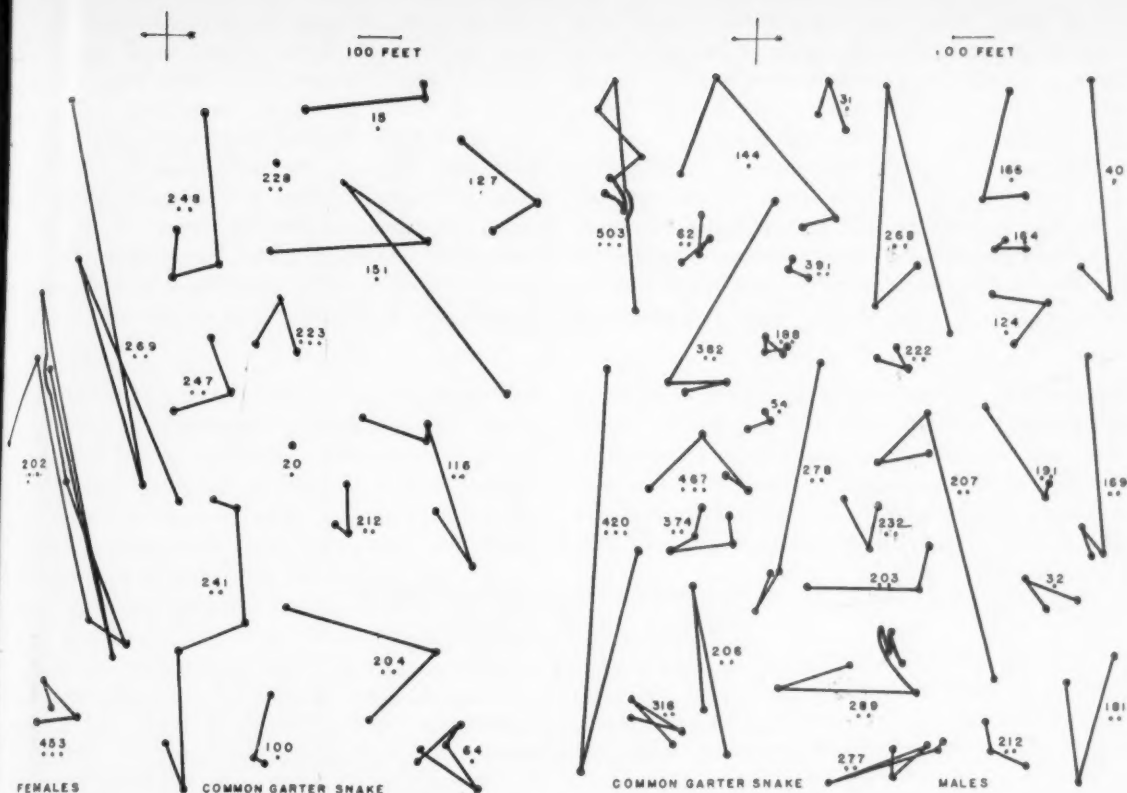
Fig. 3. Patterns of movement made by common garter snakes that have been captured three or more times; each dot represents a point of capture. The figures show activity periods in days between first and last capture. Activity period is calculated by subtracting from the interval in days between the first and last capture, those days during which the majority of these snakes are usually in hibernation. Small dots indicate the number of seasons over which the records were obtained. Notice that the distance between the first and last capture is usually less than that between the two most separated captures or that most patterns exhibit a tendency for return toward the point of original capture. The lines between dots do not indicate the route traveled by the snake but show only the sequence of captures. These patterns are used to indicate areas of limited movement for individual animals. All patterns are drawn to the same scale but otherwise are not spatially related to one another.

born during the preceding summer or were 1 year older; they were all small enough to squeeze through the tunnels of the mound. Late in the following winter this ant mound was excavated; it contained 62 juvenile snakes of seven species and 15 amphibians of three species, together with many ants, beetles, spiders, and sow bugs. It is interesting to speculate that many snakes found in cool regions spend one-half or more of their lives in a dormant state.

What does the garter snake have to fear? Its enemies are numerous. Many birds of prey, such as herons, are fond of snakes, as are foxes, coyotes, skunks, opossums, racoons, and almost any carnivore that is able to capture and kill this type of prey. Snakes also have to fear their own kind—that is, the ophiophagus king snakes. Evidence indicates that the small individuals suffer the greatest predation, many even being eaten by large frogs and

toads with ease. A great, and perhaps the greatest, destroyer of snakes is man, his automobiles, and his farm machinery.

The garter snake, if provoked, will often bite and is equipped with four rows of teeth in the upper jaw and two rows in the lower jaw. This bite has little effect and is quite harmless. On further handling, the snake may secrete a pungent musk from the glands at the base of its tail or may defecate. These actions, no doubt, would discourage many predators. Flight is the usual method of avoiding danger, and the swiftly moving striped snake creates an illusion of greater speed than actually exists. Cover such as bushes, dense grasses, or logs is the usual goal of such flight. When it is motionless in grass, a garter snake is very difficult to detect. If it is near a pool or stream, this excellent swimmer will freely take to water and, if chased, dive to the bottom and remain there for

a short time. When one is cornered on land and persistently prodded and kept from escape, it develops a negative type of behavior, forming a coil, with its head usually buried at the bottom seemingly resigned to an unavoidable nuisance.

Although the smooth, slick scales of a snake offer some protection, it still falls victim to both internal and external parasites. The mouth, lungs, intestinal tract, tail muscles, and other regions may play host to different types of parasitic worms. When one examines a garter snake closely, small red spots can often be seen between the ventral scales, particularly in the anal region. These small mites, commonly called "chiggers" or "red bugs," are the cause of much annoyance to human beings after they have been brushed from vegetation and find their way beneath the skin, causing a persistent itch. Terrestrial reptiles are the natural hosts for these ectoparasites. It has been observed that snakes with skin infections or ectoparasites shed their skins more often than those not so afflicted. Indeed, this is a unique way to get rid of an itch.

## Pillars of Science

Of all the minds that in the realm of thought
And science have attained preeminence,
Two seem to me most perfect and sublime—
Two pillars of the wisdom man has sought
Since first he questioned nature and essayed
To learn the laws immutable that hold
Forever and for all our universe.

Newton, whose mind, most powerful and serene,
Attained the goal that others sought in vain
And gave the laws that govern and foretell
The motions of a stone a child might toss,
But hold no less for heaven's largest star;
While in the realm of light his prism spread
The fruitful spectrum of the blazing sun,
His silvered mirror served to concentrate
The feeble light of planets and of stars.

As Newton built upon Galileo's toil,
So in our time, has Einstein pushed beyond
The frontiers and the bounds of Newton's scope
To new horizons and new peaks of truth.

Each earnest builder adds his stone to raise
The edifice of science, building upon
The sure foundations, laid by other men,
That have withstood the questions and the shocks
Of time. Each seeker for eternal truth
May claim a humble fellowship with these,
The masters and declarers of the laws;
For in the search for truth, the reach of every mind
Exceeds its grasp, and great and small alike
Follow a quest whose end they cannot see.

THOMSON KING

# Agricola's Position in Science

HERBERT C. AND LOU H. HOOVER

*Mr. Hoover had had an extraordinary career as a mining engineer in Asia, Europe, Africa, and America before he became the thirty-first president of the United States in 1929. In 1912 he and the late Mrs. Hoover published their translation from the Latin of Agricola's classic work,* De Re Metallica. *The following remarks are reprinted, with permission, from their introduction (pages xii–xiv).*

AGRICOLA'S education was the most thorough that his times afforded in the classics, philosophy, medicine, and sciences generally. Further, his writings disclose a most exhaustive knowledge not only of an extraordinary range of classical literature, but also of obscure manuscripts buried in the public libraries of Europe.

Our more immediate concern, however, is with the advances which were due to him in the sciences of Geology, Mineralogy, and Mining Engineering. No appreciation of these attainments can be conveyed to the reader unless he has some understanding of the dearth of knowledge in these sciences prior to Agricola's time. We have in Appendix B given a brief review of the literature extant at this period on these subjects. Furthermore, no appreciation of Agricola's contribution to science can be gained without a study of *De Ortu et Causis* and *De Natura Fossilium*, for while *De Re Metallica* is of much more general interest, it contains but incidental reference to Geology and Mineralogy. Apart from the book of Genesis, the only attempts at fundamental explanation of natural phenomena were those of the Greek Philosophers and the Alchemists. Orthodox beliefs Agricola scarcely mentions; with the Alchemists he had no patience. There can be no doubt, however, that his views are greatly colored by his deep classical learning. He was in fine to a certain distance a follower of Aristotle, Theophrastus, Strato, and other leaders of the Peripatetic school. For that matter, except for the muddy current which the alchemists had introduced into this already troubled stream, the whole thought of the learned world still flowed from the Greeks. Had he not, however, radically departed from the teachings of the Peripatetic school, his work would have been no contribution to the development of science. Certain of their teachings he repudiated with great vigour, and his laboured and detailed arguments in their refutation form the first battle in science over the results of observation *versus* inductive speculation. To use his own words: "Those things which we see with our eyes and understand by means of our senses are more clearly to be demonstrated than if learned by means of reasoning."[15] The bigoted scholasticism of his times necessitated as much care and detail in refutation of such deep-rooted beliefs, as would be demanded to-day by an attempt at a refutation of the theory of evolution, and in consequence his works are often but dry reading to any but those interested in the development of fundamental scientific theory.

In giving an appreciation of Agricola's views here and throughout the footnotes, we do not wish to convey to the reader that he was in all things free from error and from the spirit of his times, or that his theories, constructed long before the atomic theory, are of the clear-cut order which that basic hypothesis has rendered possible to later scientific speculation in these branches. His statements are sometimes much confused, but we reiterate that their clarity is as crystal to mud in comparison with those of his predecessors—and of most of his successors for over two hundred years. As an indication of his grasp of some of the wider aspects of geological phenomena we reproduce, in Appendix A, a passage from *De Ortu et Causis*, which we believe to be the first adequate declaration of the part played by erosion in mountain sculpture. But of all of Agricola's theoretical views those are of the greatest interest which relate to the origin of ore deposits, for in these matters he had the greatest opportunities of observation and the most experience. We have on page 108 reproduced and discussed his theory at considerable length, but we may repeat here, that in his propositions as to the circulation of ground waters, that ore channels are a subsequent creation to the contained rocks, and that they were filled by deposition from circulating solutions, he enunciated the foundations of our modern theory, and in so doing took a step in advance greater than that of any single subsequent authority. In his contention that ore channels were created by erosion of subterranean waters he was wrong, except for special cases, and it was not until two centuries later that a further step in advance was taken by the recognition by Van Oppel of the

part played by fissuring in these phenomena. Nor was it until about the same time that the filling of ore channels in the main by deposition from solutions was generally accepted. While Werner, two hunderd and fifty years after Agricola, is generally revered as the inspirer of the modern theory by those whose reading has taken them no farther back, we have no hesitation in asserting that of the propositions of each author, Agricola's were very much more nearly in accord with modern views. Moreover, the main result of the new ideas brought forward by Werner was to stop the march of progress for half a century, instead of speeding it forward as did those of Agricola.

In mineralogy Agricola made the first attempt at systematic treatment of the subject. His system could not be otherwise than wrongly based, as he could scarcely see forward two or three centuries to the atomic theory and our vast fund of chemical knowledge. However, based as it is upon such properties as solubility and homogeneity, and upon external characteristics such as colour, hardness, &c., it makes a most creditable advance upon Theophrastus, Dioscorides, and Albertus Magnus—his only predecessors. He is the first to assert that bismuth and antimony are true primary metals; and to some sixty actual mineral species described previous to his time he added some twenty more, and laments that there are scores unnamed.

As to Agricola's contribution to the sciences of mining and metallurgy, *De Re Metallica* speaks for itself. While he describes, for the first time, scores of methods and processes, no one would contend that they were discoveries or inventions of his own. They represent the accumulation of generations of experience and knowledge; but by him they were,

for the first time, to receive detailed and intelligent exposition. Until Schlüter's work nearly two centuries later, it was not excelled. There is no measure by which we may gauge the value of such a work to the men who followed in this profession during centuries, nor the benefits enjoyed by humanity through them.

That Agricola occupied a very considerable place in the great awakening of learning will be disputed by none except by those who place the development of science in rank far below religion, politics, literature, and art. Of wider importance than the details of his achievements in the mere confines of the particular science to which he applied himself, is the fact that he was the first to found any of the natural sciences upon research and observation, as opposed to previous fruitless speculation. The wider interest of the members of the medical profession in the development of their science than that of geologists in theirs, has led to the aggrandizement of Paracelsus, a contemporary of Agricola, as the first in deductive science. Yet no comparative study of the unparalleled egotistical ravings of this half-genius, half-alchemist, with the modest sober logic and real research and observation of Agricola, can leave a moment's doubt as to the incomparably greater position which should be attributed to the latter as the pioneer in building the foundation of science by deduction from observed phenomena. Science is the base upon which is reared the civilization of to-day, and while we give daily credit to all those who toil in the superstructure, let none forget those men who laid its first foundation stones. One of the greatest of these was Georgius Agricola.

### Smelting Four Centuries Ago

In recognition of the 400th anniversary of the death of Georgius Agricola (Georg Bauer), German scholar and scientist, on 21 November 1555, the cover illustration of this issue is a reproduction of one of the woodcuts that appeared in his famous work, *De Re Metallica*, which was published in 1556. Apparently the book was finished several years earlier, for the dedication is dated 1550. *De Re Metallica* is a complete and systematic treatise on mining and metallurgy, which appeared in 16 volumes. It is illustrated with many fine and interesting woodcuts, and an appendix contains the German equivalents for the technical terms used in the text.

The woodcut on the cover appears in Book IX and shows the operations in smelting. One can identify two furnaces, two forehearths, and a dipping pot in the background. The smelter at the right is drawing off slag with a hooked bar. The master stands at the furnace on the left and prepares the forehearth by ramming it with two rammers. In the left foreground, an assistant is drawing a bucket of water, which he will pour over the glowing slag to quench it. In the center foreground can be seen a basket made of twigs of wood intertwined, and in front of it and slightly to the right is a rabble. Just back of the basket and slightly to the right of it lies a hooked bar. In the lower right corner is a pile of ore to be smelted.

# BOOK REVIEWS

**The Development of the Concept of Electric Charge.**
Electricity from the Greeks to Coulomb. Duane Roller
and Duane H. D. Roller. Case 8, Harvard Case His-
tories in Experimental Science, James B. Conant and
Leonard K. Nash, Eds. Harvard Univ. Press, Cam-
bridge, 1954. v + 97 pp. Paper, $1.60.

This small book is a worthy member of the Harvard
Case Histories in Experimental Science. It has been
prepared by father and son, both of whom have partici-
pated fairly recently in the Harvard College course
that uses the case-history method. As a teaching de-
vice the book offers some 65 questions, none of which
are the usual physics textbook questions on electricity.
This is not a weakness but quite the opposite, for
the reader is asked to think about and discuss the
phenomena as did the original investigators.

While the book follows the historical progress of
this subject, it gives much more than a bare listing of
the historical landmarks. It emphasizes the interplay
of hypothesis and experiment so that a student can
appreciate the difficulties that confronted the investiga-
tors. There is nothing mysterious about the so-called
"scientific method" of obtaining knowledge, and the
case-history approach shows the student how these
early investigators obtained their knowledge of natural
phenomena. The methods do not depend on the sub-
ject being investigated. Whether one is discovering the
distinction between electric conductors and insulators
or is discovering a new atomic particle, the methods
are fundamentally the same, although the techniques
may differ enormously.

From the writings of Plato we find that a clear
distinction between the effects produced by a magnet
and by rubbed amber had not been made. About
A.D. 428 St. Augustine gave a factual summary of the
knowledge of phenomena exhibited by rubbed amber
and magnets. In this work, *The City of God*, Augustine
says "For my own part, I do not wish all the marvels
I have cited to be rashly accepted, for I do not myself
believe them implicitly save those that have either
come under my observation or that anyone can readily
verify, such as . . . the magnet, which by its mysterious
or sensible suction attracts the iron, but has no effect
on a straw." This is true scholarly caution.

A great advance came in the 16th century when
William Gilbert carried out many experiments and
published the book *On the Magnet,* one chapter of
which is devoted to the amber effect. Even though a
discussion of the amber effect was a diversion from the
main topic, nevertheless we find Gilbert producing a
primitive electroscope that he called a *versorium.* It
was Gilbert who introduced into our language the word
*electrics,* which was coined from the Greek word for
*amber.* Gilbert was not only a scholar but also an ex-
perimenter; a combination somewhat frowned upon
in those days when experimentation in science had not
yet become a wholly respectable activity. The 17th

century saw the beginnings of scientific societies, the
Royal Society in England and the Royal Academy of
Science in France. These were responses to an ever-
increasing interest of people in scientific work.

From the observations of attractions and repulsions
between different rubbed objects Du Fay, about 1734,
made the discovery that there were two kinds of elec-
tricity, which he called *resinous* and *vitreous.* These
terms were later changed by Franklin about 1746 to
*negative* and *positive,* thus laying the basis for a mathe-
matical treatment of this subject. The inverse square
law for electric charges was first demonstrated by
Daniel Bernouilli about 1760 and then about 1766 by
Priestley. The latter argued, from the fact that he
found no force inside an electrically charged cup,
that, as with Newtonian gravitation, the force should
vary inversely as the square of the distance. The most
direct and complete proof of the law of force between
charged bodies was given by Coulomb about 1785 using
his torsion balance.

This book shows how mankind groped its way to
knowledge. Although the methods of attack were funda-
mentally the same as those of today, the pace was
vastly different. It was nearly 2000 years after Plato
wrote about the amber effect that man knew much
about it. Possibly one might wish that 2000 years had
elapsed between the discovery of fission and an atom
bomb.

The book is well illustrated with original drawings
and quotations, and considerable care must have gone
into its preparation. It is therefore surprising to see
in such a book an error of three misplaced lines on
page 79.

This case history should be of interest to a wide
circle of people, liberal arts students, professional
scientists, and interested laymen, all of whom can profit
by reading it.

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**Theories of Perception and the Concept of Structure.**
A review and critical analysis with an introduction
to a dynamic-structural theory of behavior. Floyd
H. Allport. Wiley, New York; Chapman & Hall,
London, 1955. xxii + 709 pp. $8.

In every area of psychological inquiry theories
abound and unifying concepts are rare. To attempt to
synthesize the major principles of dissimilar theories
and thus to arrive at a truly general concept is an intel-
lectual undertaking of the first magnitude. Floyd All-
port has attempted to do this for the field of percep-
tion. History may judge the attempt a success or at
worst a splendid failure.

This large volume has three major objectives: to
present a thorough critical analysis of the problem of

perception and the methodology of studying it; to evaluate contemporary theories of perception; to offer a foundation for future systematic work in the form of a general theory of structure developed by the author during 15 years of experimental and theoretical work.

Analysis of 13 major theories of perception and a number of related viewpoints reveals extensive agreement that the perceptual act or process is characterized by internal relatedness, self-closedness or circularity, space and time building, flexibility, constancy of relationships, energic cycle or maintenance, dimensional weighting or pooling, and interaggregate facilitation or opposition.

Allport's attempt to synthesize the major contributions of the theories takes the form of a theory of the structuring of events. The proposed structural model, which provides a place for quantitative laws, consists essentially of a kinetic geometry of the self-closedness of ongoing event series and a probability concept of the events involved in such self-closed structures and their interrelationships. In this view, a perceptual act is a dynamically operating structure—a self-delimited and self-contained structuring of ongoings and events. Furthermore, Allport believes that every behavioral phenomenon follows a structural law of the type suggested by his model. Much remains to be done to clarify the theory and to test it experimentally. In a later volume the theory will be given more rigorous statement, and its implications for various fields of science will be spelled out.

This book may well become a landmark in the development of a more adequate conceptualization of perceiving. It is a "must" book for professional psychologists. It should be adopted widely for advanced undergraduate and graduate courses in perception.

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**On the Sensations of Tone as a Physiological Basis for the Theory of Music.** Hermann L. F. Helmholtz. Trans. and rev. by Alexander J. Ellis. Dover, New York, Engl. ed. 2, 1954. xix + 576 pp. Illus. $4.95.

This book is a reissue of the second English edition of Ellis' translation of Helmholtz's *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik,* which first appeared in 1863 and ran through four editions, the last in 1877. Ellis made his translation originally from the third German edition of 1870, completing it in 1875, and then carried out a thorough revision on the basis of the fourth German edition, which then appeared as the second English edition of 1885. The present issue follows the text of the second English edition with photographic accuracy, and includes also a biographic introduction and a bibliography of Helmholtz' writings by Henry Margenau.

It is unusual for a scientific work in a rapidly developing area to maintain its usefulness over three-quarters of a century, but such is the distinction of Helmholtz' book. It still belongs on the bookshelf of everyone seriously interested in acoustics and musical esthetics,

and not merely for its historical influences but also for matters of content. Helmholtz wrote his book with the aim of uniting two fields that he found to be shamefully wide apart—the field of physical and physiological acoustics on the one hand and that of musical science and esthetics on the other—and he sought to provide enough of common language and principles to bring the two into closer relationship. It would not be fair to say that he failed altogether in his purpose, for many students in both of these fields have received immeasurable value from his work, and yet the dispersive influences involved in the rapid growth of knowledge in these fields have worked to keep, or even to widen, the old separation between them. In this relationship Helmholtz' book can still be turned to with profit.

One element of Helmholtz' genius was the ability to bring together in a meaningful pattern a host of ideas that previously had been only loosely related; and although in his long career he dealt with many fields, this organizing ability is nowhere better demonstrated than in this work. Modestly he claimed little that was entirely new for the ideas and theories treated here, yet he enriched with new experiments, demonstrations, and insights nearly all of the problems that he considered. The further development of these problems was much affected, and in many instances practically determined, over many decades by his treatment of them. The following may be mentioned as especially notable areas of his influence: (i) the theory of resonance as the basis of a specific action of tones in the cochlea; (ii) the explanation of auditory quality as dependent upon tonal composition; (iii) the assertion of independence between phase relationships and the musical effects of a compound tone; (iv) the explanation of subjective overtones and combination tones as arising from distortion in the middle ear; and (v) the theory of consonance as based upon the absence of rapid beats. For each of these problems, Helmholtz' presentation has formed the reference point for subsequent consideration and study, and for two or three of these a good case can be made today for the very position that Helmholtz took nearly a century ago.

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**Qataban and Sheba.** Exploring the ancient kingdoms on the biblical spice routes of Arabia. Wendell Phillips. Harcourt, Brace, New York, 1955. xvi + 362 pp. Illus. $5.

Every scientific investigation has two aspects—the impersonal, objective research, and the personal, subjective factors involved in it. Sometimes the latter are of such interest and significance that they deserve a full report, separate from the more technical memoirs in which the former are made known to specialists in the particular subject. Such is certainly the case for an archeological exploration in a little-known region, difficult of access both because of its geographic features and because of the animosity of its inhabitants.

The leader of a scientific expedition to South Arabia would be derelict in his duty if he did not publish such an account, replete with human interest, as is the one set forth in this truly fascinating book.

Wendell Phillips is "the Richard Haliburton of archeology." Back from the wars in 1946, at 26 years of age, he organized and successfully conducted extensive surveys in Africa, extending over a period of more than 2 years. With extraordinary ability, he secured the support of many influential friends and formed the American Foundation for the Study of Man, under whose auspices he led the expeditions in Qataban, Yemen, and Dhofar during 1950, 1951, and 1952, which he describes here.

Quite evidently "all is not archaeology on an archaeological expedition." The many episodes, recounted in vivid style, deal with innumerable problems of personnel, local customs, governmental regulations, equipment, housing, transportation, and methods of excavation. At times, one has great difficulty in sorting out the chronological sequence of events, but one's interest in the vicissitudes and accomplishments of the intrepid and ingenious members of the expeditions and in the regions where they worked is always sustained at a high pitch.

Enough is told about the scientific results to whet one's appetite—if one is concerned with the history of the Middle East during the last 10 centuries B.C. and the first 10 centuries A.D.—for the scholarly reports soon to be issued by the Johns Hopkins University Press. At Beihar and Timna, in Qataban, the excavations uncovered ancient cities with innumerable inscriptions, statues, and other artifacts. Marib, in Yemen, was the ancient capital of Sheba. Near it, the party excavated the magnificent Temple Awwan but were forced by the local authorities to leave in haste before they had uncovered any relics of the biblical Queen of Sheba for which they had been searching.

Regardless of one's archeological interest, this is a thrilling account of modern adventure in the deserts and mountains of southern Arabia. It affords many significant insights concerning one of the last of the world's relatively unknown areas.

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**Handbook of Algae.** With special reference to Tennessee and the Southeastern United States. Herman Silva Forest. Univ. of Tennessee Press, Knoxville, 1954. 467 pp. Illus. $4.75.

Fresh-water algae in the United States have been given a generous amount of attention floristically during the past decade, as is evidenced by the number of handbooks and compendiums that have appeared recently. This volume, the latest, represents a sincere, conscientious, and rather ambitious attempt to bring a large number of organisms under the cover of one small book. This is no small task, and the author has been successful by trimming and pairing and deleting,

thus being forced to stop a little short of an ideal goal for a "handbook." Very properly, and in all fairness to the "customer," the book should be entitled "Handbook of Tennessee Algae" inasmuch as only Tennessee localities are indicated (with some references to other southeastern states). Even so, a quick count discloses that more than 250 genera and more than 900 species and forms are treated, and because practically all of these have an almost world-wide distribution the usefulness of the volume is not necessarily limited.

There is an artificial key to genera, followed by keys to species for almost every genus. Preliminary application of the keys indicates that they are exact and quite workable for the less experienced student of the algae. There are 699 text figures illustrating species and also descriptive terms. In addition to descriptions for most species, the author includes helpful critical notes pertaining to species characteristics of taxonomic value. It is necessary to point out that whereas good, brief descriptions of species are given in a vast majority of cases, not a few are incorrect, so that the reader must be advised to compare identifications with descriptions in other authoritative works. Selecting at random, *Cosmarium pyramidatum*, page 227, Fig. 291, is both described and figured incorrectly—admittedly a minor matter—but the experienced reader will wonder why the eyespot of *Euglena viridis* is referred to as not having been "heretofore recorded." For each species a location is given in Tennessee (or some other southeastern state), but there are scanty habitat notes and, probably because of space limitations, no ecology.

In attempting to deal adequately and helpfully with so many species in so many different phyla of algae in a scant 442 pages, the author himself realizes a few shortcomings of the volume. The illustrations are crowded and so reduced in reproduction that much detail is lost in those figures where the author was considerate enough to include some detail. This is unfortunate because the book will find a usefulness mostly among less experienced students of aquatic biology for whom well-executed drawings are imperative. There is some detraction from high professional level because of the inadequacy of the drawings and also because of the format. No doubt some readers will agree that the interior cover decorations, for example, are not in tune with good composition, and the portable typewriter style of printing does not lend an esthetic quality but rather is distracting in some places because of incorrect spacing of letters and words. There is the usual sprinkling of typographic errors and, although they are not damaging or misleading in most cases, they are disturbing to any author because he realizes that such errors do not fortify faith in his exactitude on the part of the reader. Colloquialisms and new words (coined by converting adjectives to verbs, for example) appear often enough throughout the book to invoke a query as to how the book was edited. Anyone reviewing the book who is at all editorially minded will come to the conclusion that more "blue-pencil work" would have helped the author. The use of *epiphytic* when the author means *epizoic* would have been corrected, and "Species Not Included in the Key" when

they are not included in the *text* in this case would have been caught.

The user will find many helps toward successful identification of algal species in both the keys and the descriptions. Possibly he will be bothered by the lack of complete citations in the text to bibliographic references. In cases of two or more references for the same author, for example, the text gives no indication of which reference is pertinent. In the bibliography the author has chosen to omit reference to his own doctoral thesis on which this work is based and which is incorporated in the book. The nature and context of the introduction accordingly are related more to the thesis than to a "handbook," thereby leaving something to be desired on the part of the less experienced reader who seeks information in a book with this title.

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**Small-Fruit Culture.** A text for instruction and reference work and a guide for field practice. James Sheldon Shoemaker. McGraw-Hill, New York–London, ed. 3, 1955. vii + 447 pp. Illus. $6.50.

As in previous editions, this new book covers the subjects of grapes, strawberries, brambles, currants and gooseberries, blueberries and cranberries. The most recent information pertaining to improved cultural practices, newer varieties, modern methods of disease and insect control and a greatly enlarged discussion on irrigation practices is included in the text.

The author has brought together the most recent investigational findings from experiment stations over the country, as is evidenced by the listing of 621 references, which are conveniently numbered and listed in the back of the book. More than 200 new references are listed in this edition. Many new illustrations are included, and the discussions cover the new and important developments that have occurred in recent years. Many new features have been added with reference to pruning and training of grapes and brambles, and of special interest is the "30 plus 10" scale for grapes.

Other topics given special attention are French hybrid grapes, everbearing varieties of both strawberries and raspberries, weed control by chemical herbicides, mulching practices, hardiness and winter injury, the influence of chemicals as growth regulators, the influence of minor nutrient elements and other fertilizer practices, and the basic role of primary, secondary and tertiary flowers in the strawberry cluster.

Growers will welcome the discussion of grass control in strawberry plantings by confining geese in the area because this is one of the problems of great concern. The improved methods of fruit preservation by freezing and the use of mechanical pickers for bramble fruits are adequately covered.

Considerable improvement has been made by the addition of numerous headings and subheadings throughout the text, and these add greatly to the interest of the book, by making the topics stand out more clearly. The volume is carefully indexed and excellently arranged and brings together the latest information on the commonly grown small fruits. It makes available a splendid textbook for teaching and a ready reference for growers and investigators, and is the only modern volume covering the specific field of small fruits.

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**Time Counts.** Harold Watkins. Philosophical Library, New York, 1954. vi + 274 pp. Illus. + plates. $3.75.

A member of the British Advisory Council of the World Calendar Association, Harold Watkins, has incorporated in this book the story of the changes and developments that have resulted in the calendar as we now know it and a résumé of the current movements for an adoption of the World Calendar in 1956.

He begins with the fourth Earl of Chesterfield's account of how the Greeks measured time by the Olympiad, and he continues the history of chronology through the Gregorian Calendar. The major portion of the book deals with the present efforts for reforming the Gregorian Calendar. These modern reform movements have been going on since 1834. According to Watkins, the World Calendar Association International had reason to hope that the United Nations would adopt the World Calendar in time for the change-over 31 December 1950, a time when the Gregorian and World Calendars would coincide. However, the calendar motion was dropped from the agenda of the United Nations in September 1953. The author states that the next coinciding date for the two calendars is 1 January 1956, and that it is the goal of the association to work for adoption of their proposed calendar reform, by the United Nations, in time for the change-over 1 January 1956.

Those who are interested in the history of time-counting and in present-day efforts for calendar reform will find both summarized in *Time Counts*.

**Nuclear Physics.** Irving Kaplan. Addison-Wesley, Cambridge, Mass., 1955. xi + 609 pp. Illus. $10.

This is an introductory nuclear physics textbook intended for students with no more background in atomic physics than is available in a 2-year beginning course. The book is divided into three parts: the first 150 pages being devoted to the atomic physics background necessary for the development of nuclear concepts, the middle 300 pages to the physics of the nucleus, and the last 150 pages to such special topics as neutron physics, fission, reactors, and particle accelerators.

In covering so wide a field, an author risks losing the engineering students, who are likely to find the pace too fast and the discussion inadequate, as well as the serious physics students with a good background in atomic physics and elementary quantum theory, who are likely to find the treatment too superficial. Although Kaplan

has aimed his book squarely between the two groups of
students, I suspect that engineering students with only
an elementary physics background will find the going
rather rough in places. These students should find the
background material in the first part of the book well
within their grasp, however. The 20-page chapter on
relativity, for example, sets forth the principles of the
special theory in a clear and understandable fashion.

In attempting to keep the discussion as simple as pos-
sible, the author sometimes sacrifices some important
aspects of nuclear physics. He says, for example, that
the electric quadrupole moment cannot be discussed in
a simple way and makes no further mention of it, ex-
cept to note it as one factor in support of the shell model.
I believe that the quadrupole moment can be under-
stood fully as well by students at this level as can the
theory of beta-decay, which Kaplan discusses at some
length. There is also scant mention of parity and statis-
tics. I would have liked more discussion on these topics.

With the exceptions noted, the part of the book de-
voted to the nucleus itself covers the concepts of classi-
cal nuclear physics, together with the experimental basis
of these concepts, in a logical, coherent manner. There
is only slight discussion of high-energy nuclear physics
and of meson physics.

One aspect of the book worth noting is the treatment
of the apparatus of nuclear physics. Too often elemen-
tary textbooks overemphasize the apparatus at the ex-
pense of the physics. Kaplan has discussed apparatus and
methods of measurement where such discussion con-
tributes to an understanding of the physics involved, but
the emphasis is always on the physics.

Another feature of the book that I like is the exten-
sive list of references, at the end of every chapter, to the
original literature. The serious physics student will find
this especially helpful. Altogether this book is a worth-
while addition to the rather small list of good books on
elementary nuclear physics.

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**The Prevalence of People.** Marston Bates. Scribner,
New York, 1955. 283 pp. $3.95.

As in previous books, Marston Bates demonstrates
here that nontechnical scientific writing may be inform-
ative but not boring, and readable without being
misleading. He is to be commended for not stressing
the more sensational and highly marketable aspects of
the population problem, which are so often the subject
of doctrinal presentation, symbolized by either the
cornucopia or the bare cupboard. Instead he examines
extensively the past and present of human densities
and largely eschews explicit prediction. Often infer-
ences, although clear, are merely implied. Although
of great significance, human population problems are
not easy to explore within these limits; the success of
the book hinges largely on the peculiarly felicitous dis-
cursive style, which holds the reader's interest.

Present and past population estimates are discussed
in connection with their nexus of determinants: births,
deaths, and migrations. The prevalence of attempts to
limit family size and the historically most important
sources of mortality are considered. These more biologi-
cal aspects are viewed throughout in a context of
sociology and anthropology, since, in the author's words
"If there is a basic thesis in this book of mine, it is
that numbers of men, the prevalence of people, can be
understood in cultural terms."

Without attempting detailed documentation, Bates
presents an impressive body of information. Data are
well interpreted, and areas of conjecture are clearly
defined. The summarizing chapters may not be com-
pletely convincing in making a whole of the parts, since
vital pieces of knowledge are missing, but their lack
cannot be blamed on the author alone. If fault must
be found, it is a lack of discrimination; the approaches
to the main subject are oblique, one of the reasons for
the book's charm. But what should be approaches in
some cases are tangential digressions not pertinent to
the subject. This, for example, applies to a chapter
on eugenics, space for which might have been used
more profitably in amplifying other parts. This criti-
cism may be mere quibbling, however, since the major
intent of the book is to provide an introduction to
problems of human population. Not only does it fulfil
this purpose, but the list of references should supply
an abundant range of stimulating reading.

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**The Human Organism.** Russell Myles DeCoursey. Mc-
Graw-Hill, New York–London, 1955. vii + 550 pp.
Illus. + plate. $5.75.

This textbook is planned for college freshmen and
sophomores who have taken an elementary course in
biological science and who do not expect to become
physicians, nurses, or members of allied professions. The
purpose of the book is to give students basic information
that will enable them to understand phenomena of gen-
eral interest and significance—for example, the action of
hormones, common vision defects, reproduction. The
author counts on the student's general interest in under-
standing himself to give him more enthusiasm for inte-
grated human anatomy and physiology "than could be
roused by any laboratory animal."

The book opens with a detailed and somewhat tech-
nical discussion of cytology and histology, followed by
chapters on the bony framework, the muscles, and the
other classic "systems." These include much anatomical
detail, well organized by means of side heads. The chap-
ter on "Blood" seems unusually satisfactory. The chap-
ter on "Food, nutrition, and metabolism" is practical.
Throughout the book the author uses facts of embryology
to throw light on the structure and functioning of various
organs and organ systems. A brief chapter on "Human
development" is placed near the end of the book.

The focus of interest is on functions of organs; there is

nowhere any consideration of the human being as a functioning whole. The basic information set forth could be used by a skillful teacher as a sound background for health instruction, although the book itself gives a minimum of attention to hygiene as such.

The illustrations are numerous and well chosen. The anatomical drawings and physiological diagrams are beautifully clear. There is appended to each chapter a set of questions for the student's guidance and a short list of references to more technical treatments of the immediate topic. The glossary and index are adequate and useful.

The chief value of *The Human Organism* is that it serves a group of students whose interests are stronger, more varied, and more penetrating than can be satisfied by the ordinary textbooks in this general field.

ANITA D. LATON
*Health and Hygiene Department, San Jose State College*

**L'Acoustique des Orthoptères.** Proceedings of a symposium held 5–8 Apr. 1954, at Jouy-en-Josas, France. Institut National de la Recherche Agronomique, France, 1955 (Order from Régisseur des Publications, I. N. R. A., Paris). 448 pp. Illus. $8.

Among the most familiar of insects that produce sounds and have well-developed sound-receiving organs are the grasshoppers, katydids, crickets, and their relatives—members of the order Orthoptera. In spite of many studies on their acoustic behavior, our knowledge of the complex physiological and social mechanisms involved remains meager. Development of newer sound-recording and analyzing equipment now makes possible precise investigations in this field. To facilitate the sharing of newer research data and ideas on the acoustics of Orthoptera, an international symposium was organized in 1954 by R.-G. Busnel, directeur du Laboratoire de Physiologie Acoustique, I. N. R. A. Twenty-three papers were presented, and they are published in this book. All were either originally in the French language or have been translated into French for publication.

The first section (7 papers) deals with acoustic definitions and concepts and with recording and analyzing equipment useful for studies of insect sounds. The second section (10 papers) deals with the structure and action of sound-producing organs in Orthoptera. The third section (6 papers) deals with reception of sounds and reactions to natural and artificial sounds by these insects. The book concludes with a bibliography of 1175 titles on sound production and reception by insects in general.

The lengths and coverage of these papers differ widely. Some are preliminary reports of work in progress, others are detailed presentations of results, and others are reviews of published works or theoretical discussions. The coverage is topical and not complete or integrated. The purpose is to present active research rather than to cover the subject systematically. The fact that 23 papers on the acoustics of only one of the many orders of insects can be presented with so little

repetition is proof of the progress already made. The symposium, however, represents only a beginning, a look toward definitive studies to come as newer acoustic tools and biological methods for field studies are utilized fully.

HUBERT FRINGS
*Department of Zoology and Entomology,*
*Pennsylvania State University*

**The Human Brain.** John Pfeiffer. Harper, New York, 1955. viii + 273 pp. Illus. + plates. $3.75.

There can be no doubt concerning John Pfeiffer's principal thesis, that the brain is an astounding organ, that its modes of function are devious and shrouded in mystery. Indeed this can be called a wonder book in the sense that expression of this attitude toward this organ appears to be the author's chief interest rather than presentation of any well-structured and well-supported analysis of the brain's mechanism of function.

Unquestionably the author has sought information and has marshaled an impressive array of interesting facts. His approach to the subject is dynamic and uninhibited. His dramatization of the situation probably will make this book more acceptable to the general reader than are more orthodox scientific treatises. A listing of a few of the chapter headings illustrates this point very well: "Man's evolving brain"; "Pathways of emotion"; "Remembrance of things past"; "The sacred disease"; "A visit to Manteno"; "The thinking machine". The presentation of evidence is not precise, and source material is not quoted; consequently this volume will not be much help to a beginning student. More experienced physiologists and physicians should obtain pleasure from reading it, and certainly many things are mentioned that any reader is likely not to know.

Despite the fact that this work cannot be considered a scientific contribution or a source of reliable factual information, it may serve to dispel some of the superstitions shrouding this field and to encourage a more natural approach to the acceptance and treatment of psychiatric disorders. The book is certainly well written and by standards of the popular press is of considerable merit.

CHANDLER McC. BROOKS
*Department of Physiology, State University of New York*

**Doctors in the Sky.** The story of the Aero-Medical Association. Robert J. Benford. Thomas, Springfield, Ill., 1955. xv + 326 pp. Illus. $8.75.

R. J. Benford did a real service for those who have a professional or amateur interest in aviation medicine when he undertook to collect in one place the many data that make up this book. *Doctors in the Sky* is the history of the Aero-Medical Association and, as such, has a specific interest for flight surgeons past and present and for all flying personnel who are interested in, and ap-

preciative of, the many contributions that aviation medicine has made to their survival. The story of the Aero-Medical Association down the years is the collective story of the flight surgeons and aviation biologists who as individuals in this country did the pioneering research and development that permitted man to travel safely from the earth's surface and hopefully to come home again.

The author is to be commended for taking the initiative in collecting for posterity not only the factual history of an organization and the accomplishments of its members but also the many small anecdotal bits and pieces that can be so easily lost with the passing of each generation and yet reveal so much.

The book is well printed and has numerous pictures, primarily of people. For those who have interest in the men who have made the advances in aviation biology in this country and the Aero-Medical Association of which they were members, *Doctors in the Sky* is recommended as a source book.

DONALD W. HASTINGS
*Department of Psychiatry and Neurology,*
*University of Minnesota*

**The Tree of Culture.** Ralph Linton. Knopf, New York, 1955. xiv + 692 pp. Illus. + plates. $5.75.

An old banyan tree looks like a miniature jungle, with numerous trunks amid a tangle of interlacing branches. Yet we know that a banyan starts from a single stem whose branches drop aerial roots that in time become trunks with branches of their own, and so on, to turn into a small forest that is, nonetheless, a single growing plant. In the same sense, the cultures of mankind form, despite their divergences, a "single growing plant." And this is what Ralph Linton set out to demonstrate in the present book, which was nearly finished at the time of his death and was seen through the press by Adelin Linton.

Few men of our own or any other time, in my opinion, have possessed the depth and sweep of knowledge combined with the scientific imagination to attempt this task. And fewer still have been able to translate them to paper in simple language and in a style that grips and holds the reader, whether specialist or layman.

This is no unilineal evolutionism; the story of human cultural developments in six main trunks of the tree sprouted from the original paleolithic stem: the Southeast Asia complex, Southwest Asia and Europe, the Mediterranean, Africa, the Orient, and the New World. Preceding these accounts are some 170 pages dealing with the original "roots," the soil in which they grew, and the principles as Linton saw them involved in such growth. In the short space allotted to this notice no attempt can be made to outline the substantive content or to comment on it and the theory and insight whereby it is interpreted.

The book will probably provoke some discussion among specialists, with respect to details of both facts and theory. Yet I think that no one with the slightest interest in man's development or his present condition can afford to miss the experience of reading it. Here is scholarship without pedantry, wit without vulgarity, timeliness rooted in the depths of time. Here is a true mirror for man and his works from the earliest beginnings to the present.

JOHN GILLIN
*Center for Advanced Study in the Behavioral Sciences*

**Descriptive College Physics.** Harvey E. White. Van Nostrand, New York; Macmillan, London, 1955. x + 485 pp. Illus. + plates. $5.75.

By cutting out some material from the author's well-known liberal arts textbook, *Classical and Modern Physics,* the present volume was made short enough to be covered in a one-semester course. It is intended for students who do not major in any of the physical or life sciences. The author uses it in a survey course in which the students are not required to solve problems. Problems, however, are listed at the end of each chapter.

The conventional order of presentation is followed, with eight chapters on mechanics, five on properties of matter, four on heat, four on sound, three on light, five on electricity, four on atomic physics, and seven on nuclear physics. Thus, more space is devoted to modern physics than to any classical topic. Optics is slighted the most, with no material on interference, diffraction, or polarization. There is, however, an attractively illustrated chapter on color.

The author has great skill in depicting physical situations with the aid of simple line sketches. The book abounds with drawings, photographs, and color plates and should be attractive and appealing to the liberal arts student. There are occasional biographical footnotes and, at the end of the book, seven appendixes containing atomic and nuclear information. The index is extensive. All in all, the author has satisfied very well indeed the purpose for which this book was intended.

MARK W. ZEMANSKY
*Department of Physics,*
*City College of New York*

**Electricity.** Eric deVille. Penguin, 1955. 155 pp. Illus. + plates. $0.65.

This book is a popular exposition of the history and nature of electrical science. It is filled with historical errors that make it quite clear that the author has not consulted even reasonably modern sources. Enough information is now available in the history of electricity to make one wonder whether there is any point in publication of additional popular "histories" that simply reproduce the errors of their predecessors. A good popular history of electricity would be of value; the value of the present volume is questionable.

DUANE H. D. ROLLER
*Department of History, University of Oklahoma*

# Books Reviewed in SCIENCE

## 2 September

*Molecular Vibrations,* E. Bright Wilson, Jr., J. C. Decius, Paul C. Cross (McGraw-Hill). Reviewed by G. Herzberg.

*Numerical Methods,* Andrew D. Booth (Academic Press; Butterworths). Reviewed by Mina Rees.

*Electrons, Atoms, Metals and Alloys,* William Hume-Rothery (Philosophical Library; Iliffe). Reviewed by J. S. Koehler.

*Political Systems of Highland Burma,* E. R. Leach (Harvard Univ. Press). Reviewed by Morton H. Fried.

*An Introduction to Stochastic Processes with Special Reference to Methods and Applications,* M. S. Bartlett (Cambridge Univ. Press). Reviewed by Seymour Geisser.

*The Lipids.* vol. II, *Biochemistry,* Harry J. Deuel, Jr. (Interscience). Reviewed by J. B. Brown.

*Theories Relativistes de la Gravitation et de l'Electromagnetisme,* A. Lichnerowica (Masson). Reviewed by P. LeCorbeiller.

*La Mécanique au XVIIᵉ Siècle (des Antécédents Scolastiques à la Pensée Classique),* René Dugas (Dunod). Reviewed by I. Bernard Cohen.

*Traité de Zoologie: Anatomie, Systématique, Biologie.* vol. XII, *Vertébrés,* Pierre P. Grassé, Ed. (Masson). Reviewed by Morris Foster.

*Geology in Engineering,* John R. Schultz and Arthur B. Cleaves (Wiley; Chapman & Hall). Reviewed by Robert H. Nesbitt.

*Mathematics for the Chemist,* G. J. Kynch (Academic Press; Butterworths). Reviewed by John K. Taylor.

*Transform Calculus with an Introduction to Complex Variables,* E. J. Scott (Harper). Reviewed by Alston S. Householder.

*Medical Uses of Cortisone,* Francis D. W. Lukens, Ed. (Blakiston-McGraw-Hill).

## 9 September

*Electroacoustics,* Frederick V. Hunt (Wiley; Chapman & Hall). Reviewed by Hugh S. Knowles.

*A Million Random Digits with 100,000 Normal Deviates,* Rand Corp. (Free Press). Reviewed by Carl F. Kossack.

*Endothelium,* Rudolf Altschul (Macmillan). Reviewed by Arnold Lazarow.

*Antibiotics Annual 1954–1955,* Henry Welch and Felix Marti-Ibaney, Eds. (Medical Encyclopedia). Reviewed by Chester S. Keefer.

*The Chemistry of Synthetic Dyes and Pigments,* H. A. Lubs, Ed. (Reinhold). Reviewed by Wallace R. Brode.

*Organic Reactions,* Roger Adams, Ed. (Wiley; Chapman & Hall). Reviewed by Robert C. Elderfield.

*Electrolyte Solutions,* R. A. Robinson and R. H. Stokes (Academic Press). Reviewed by Theodore Shedlovsky.

*Papirova Chromatografie,* I. M. Hais and K. Macek, Eds. (Czechoslovakian Academy of Sciences). Reviewed by Harold G. Cassidy.

*The Method of Trigonometrical Sums in the Theory of Numbers,* I. M. Vinogradov. (Interscience). Reviewed by S. Chowla.

*Preservation and Transplantation of Normal Tissues,* G. E. W. Wolstenholme and Margaret P. Cameron, Eds. (Little, Brown).

## 16 September

*The Hypophyseal Growth Hormone, Nature and Actions,* Richard W. Smith, Oliver H. Gaebler, C. N. H. Long, Eds. (Blakiston Div., McGraw-Hill). Reviewed by Joseph T. Velardo.

*Protective Coatings for Metals,* R. M. Burns and W. W. Bradley (Reinhold). Reviewed by Vernon A. Lamb.

*Biochemistry of the Aminosugars,* P. W. Kent and M. W. Whitehouse (Academic Press; Butterworths). Reviewed by Karl Meyer.

*Vitamins in Theory and Practice,* Leslie J. Harris (Cambridge Univ. Press). Reviewed by B. F. Chow.

*Autoradiography in Biology and Medicine,* George A. Boyd (Academic Press). Reviewed by Herman Yagoda.

*Organic Solvents: Physical Properties and Methods of Purification,* Arnold Weissberger, Ed. (Interscience). Reviewed by Carleton W. Roberts.

*Fluoridation as a Public Health Measure,* J. H. Shaw, Ed. (AAAS). Reviewed by H. Trendley Dean.

*Manganese,* A. H. Sully (Academic Press; Butterworths). Reviewed by Earl S. Greiner.

## 23 September

*Thomas Bradwardine His Tractatus de Proportionibus,* H. Lamar Crosby, Jr., Ed. and Trans. (Univ. of Wisconsin Press). Reviewed by Carl B. Boyer.

*Morbidity in the Municipal Hospitals of the City of New York,* Marta Fraenkel and Carl L. Erhardt (Russell Sage Foundation). Reviewed by Antonio Ciocco.

*Introduction to Psychiatry,* O. Spurgeon English and Stuart M. Finch (Norton). Reviewed by R. D. Craig.

*Bibliography on Physical Electronics,* Wayne B. Nottingham and staff (Addison-Wesley). Reviewed by B. R. Gossick.

*Atomic and Nuclear Physics,* Robert S. Shankland (Macmillan). Reviewed by W. Selove.

*Supplement No. 2, 1955, of Cancer Research,* various contributors (Univ. of Chicago Press).

*Scientific and Technical Societies of the United States and Canada* (National Acad. of Sciences–National Research Council).

## 30 September

*Approximations for Digital Computers,* Cecil Hastings, Jr. (Princeton Univ.). Reviewed by A. S. Householder.

*Speech: Code, Meaning, and Communication,* John W. Black and Wilbur E. Moore (McGraw-Hill). Reviewed by Wendell Johnson.

*Methods of Quantitative Micro-Analysis,* R. F. Milton and W. A. Waters, Eds. (St Martin's Press; Arnold). Reviewed by John H. Yoe.

*Elementary Theory of Nuclear Shell Structure,* Maria Goeppert Mayer and J. Hans D. Jensen (Wiley; Chapman & Hall). Reviewed by Katharine Way.

*Canadian Cancer Conference,* vol. I, R. W. Begg, Ed. (Academic Press). Reviewed by Sigismund Peller.

*Letalfaktoren in ihrer Bedeutung für Erbpathologie und Genphysiologie der Entwicklung,* Ernst Hadorn (Thieme). Reviewed by Walter Landauer.

*Radiation Biology.* vol. II, *Ultraviolet and Related Radiations,* Alexander Hollaender, Ed. (McGraw-Hill). Reviewed by Richard B. Roberts.

*Aux Confins de la Vie,* P. Morand (Masson). Reviewed by S. E. Luria.

# ❧ New Books ❧

**Industrial and Manufacturing Chemistry.** pt. I, *Organic*; ed. 7; 752 pp. pt. II (in 2 vols.), *Inorganic*; ed. 6; 1091 pp. Geoffrey Martin. Philosophical Library, New York, 1955. $50 per set.

**Schools of Psychoanalytic Thought.** An exposition, critique, and attempt at integration. Ruth L. Munroe. Dryden Press, New York, 1955. 670 pp. $7.50.

**Introduction to Chemical Pharmacology.** R. B. Barlow. Wiley, New York; Methuen, London, 1955. 343 pp. $6.25.

**The Decline of Wisdom.** Gabriel Marcel. Philosophical Library, New York, 1955. 56 pp. $2.50.

**Eternal Energies.** John H. Ward. Richard Smith, Rindge, N. H., 1955. 286 pp. $3.50.

**Problèmes de structures, d'ultrastructures et de fonctions cellulaires.** J. André Thomas. Masson, Paris, 1955. 358 pp. Paper, F. 3000.

**Rome beyond the Imperial Frontiers.** Mortimer Wheeler. Philosophical Library, New York, 1955. 192 pp. $7.50.

**Pilot Plant Techniques of Submerged Fermentation.** Special English edition of Rendiconti Instituto Superiore di Sanita, vol. 17. Fondazione Emanuele Paterno, Rome, 1954. (Distrib. by Interscience, New York). 243 pp.. Paper, $8.10.

**Crust of the Earth.** A symposium. Arie Poldervaart, Ed. Geological Soc. of America, New York, 1955. 762 pp. $6.50.

**The Liver and Cancer.** A new cancer theory. Kasper Blond. John Wright, Bristol, Eng., 1955. (Distrib. by Williams & Wilkins, Baltimore). 220 pp. $6.50.

**Fundamental Fundamentals.** Albert Brill. Philosophical Library, New York, 1955. 199 pp. $3.75.

**A Dictionary of Terms in Pharmacognosy and Other Divisions of Economic Botany.** George Macdonald Hocking. Thomas, Springfield, Ill., 1955. 284 pp. $9.75.

**Altes und Neues über knovex Körper.** Band III. H. Hadwiger. Birkhäuser, Basel, Switzerland, 1955. 115 pp. F. 13.50.

**General Chemistry Workbook.** Conway Pierce and R. Nelson Smith. Freeman, San Francisco, 1955. 255 pp. $1.65.

**Practicas de Fisiologia.** Eduardo Briese. Instituto de Fisiologia, Universidad de los Andes, Merida, Venezuela, 1955. 232 pp.

**Clinical Toxicology.** Clinton H. Thienes and Thomas Haley. Lea & Febiger, Philadelphia, rev. ed. 3, 1955. 457 pp. $6.50.

**Nuclear and Radiochemistry.** Rev. version of *Introduction to Radiochemistry*. Gerhart Friedlander and Joseph W. Kennedy. Wiley, New York; Chapman & Hall, London, 1955. 468 pp. $7.50.

**Haplorhini: Tarsioidea.** vol. II of *Primates: Comparative Anatomy and Taxonomy*. W. C. Osman Hill. Interscience, New York; University Press, Edinburgh, 1955. 347 pp. $9.50.

**The Origin of Vertebrates.** N. J. Berrill. Clarendon Press, Oxford, 1955. 257 pp. $4.

**Chemistry of the Solid State.** W. E. Garner, Ed. Academic Press, New York; Butterworths, London, 1955. 417 pp. $8.80.

**Magic and Schizophrenia.** Géza Róheim. Warner Muensterberger, Ed. International Universities Press, New York, 1955. 230 pp. $4.50.

**Vector and Tensor Analysis.** Nathaniel Coburn. Macmillan, New York, 1955. 341 pp.

**Biochemical Preparations.** vol. 4. W. W. Westerfeld, Ed. Wiley, New York; Chapman & Hall, London, 1955. 108 pp. $3.75.

**Energy and Society.** The relation between energy, social change, and economic development. Fred Cottrell. McGraw-Hill, New York, 1955. 330 pp. $6.

**Tungsten.** Its history, geology ore-dressing, metallurgy, chemistry, analysis, applications, and economics. American Chemical Soc. Monogr. No. 94. K. C. Li and Chung Yu Wang. Reinhold, New York; Chapman & Hall, London, ed. 3, 1955. 506 pp. $14.

**Monographs on Topics of Modern Mathematics Relevant to the Elementary Field.** J. W. A. Young, Ed.; with a new introduction by Morris Kline. Dover, New York, 1955. 416 pp. Cloth, $3.95; paper, $1.90.

**Diffusion and Heat Exchange in Chemical Kinetics.** D. A. Frank-Kamenetskii. Trans. by N. Thon. Princeton Univ. Press, Princeton, N.J. 1955. 370 pp. $6.

**Magnetic Materials in the Electrical Industry.** P. R. Bardell, Philosophical Library, New York, 1955. 288 pp. $10.

**Contributions to Plant Anatomy.** vol. 15. Irving W. Bailey. Chronica Botanica, Waltham, Mass.; Stechert-Hafner, New York, 1954. 262 pp. $7.50.

**Introductory Nuclear Physics.** David Halliday. Wiley, New York; Chapman & Hall, London, ed. 2, 1955. 493 pp. $7.50.

**Hydrodynamics.** A study in logic, fact and similitude. Garrett Birkhoff. Dover, New York, 1955. 186 pp. Cloth, $3.50; paper, $1.75.

**Physics and Microphysics.** Louis De Broglie. Trans. by Martin Davidson; foreword by A. Einstein. Pantheon, New York, 1955. 286 pp. $4.50.

**Theory of Groups of Finite Order.** W. Burnside. Dover, New York, ed. 2, 1955. 512 pp. Cloth, $3.95; paper, $2.

**Seven Men among the Penguins.** An Antartic venture. Mario Marrett. Trans. from the French by Edward Fitzgerald. Harcourt, Brace, New York, 1955. 269 pp. $4.50.

**Directory of Scientific Research Organizations in the Union of South Africa.** D. Ryle Masson, Ed. Van Schaik, Pretoria, 1955. 123 pp. 25s.

**Embryologie.** Ein Lehrbuch auf Allgemein Biologischer Grundlage. Dietrich Starck. Thieme, Stuttgart, Germany, 1955. 688 pp. $18.55.

**Non-Euclidean Geometry.** A critical and historical study of its developments. Roberto Bonolo. Trans. by H. S. Carslaw. Dover, New York, 1955. 389 pp. Cloth, $3.95; paper, $1.90.

**Electro-Magnetic Machines.** R. Langlois-Berthelot. Trans. and rev. in collaboration with H. M. Clarke. Philosophical Library, New York, 1955. 535 pp. $15.

**Introduction to Demography.** Society of Actuaries' textbook. Mortimer Spiegelman. The Society, Chicago, 1955. 309 pp. $6.

**Anti-Composition Tables for Carbon Compounds (CH, CHO, CHS, and CHOS).** H. H. Hatt, T. Pearcey, A. Z. Szumer, compilers. Cambridge Univ. Press, London, 1955. 191 pp. $4.

**A Classification for Medical and Veterinary Libraries.** Cyril C. Barnard. Lewis, London, ed. 2, 1955. 278 pp. £4 4s.

**Counseling in Medical Genetics.** Sheldon C. Reed. Saunders, Philadelphia, 1955. 268 pp. $4.

**Advances in Genetics.** vol. VII. M. Demerec, Ed. Academic Press, New York, 1955. 309 pp. $7.50.

**Chemotherapy of Malaria.** Gordon Covell, G. Robert Coatney, John W. Field, Jaswant Singh. WHO Monogr. Ser. No. 27. World Health Organization, Geneva, 1955. 123 pp. $3.25.

**A Handbook of Hospital Psychiatry.** A practical guide to therapy. Louis Linn. International Universities Press, New York, 1955. 560 pp. $10.

**The Hormones.** Physiology, chemistry and applications. vol. III. Gregory Pincus and Kenneth V. Thimann, Eds. Academic Press, New York, 1955. 1012 pp. $22.

**Laboratory Outlines and Notebook of Organic Chemistry.** Cecil E. Boord, Wallace R. Brode, Roy G. Bossert. Wiley, New York and Chapman & Hall, London, ed. 3, 1955. 314 pp. $3.90.

**Boundary Layer Theory.** Hermann Schlichting. Trans. by J. Kestin. McGraw-Hill, New York; Pergamon, London; Braun, Karlsruhe, Germany, 1955. 535 pp. $15.

**The Miracle of Light and Power.** How electricity, gas and steam are produced for home and industry. Burr W. Leyson. Dutton, New York, 1955. 186 pp. $3.50.

**Qualitative Organic Analysis and Scientific Method.** A. McGookin, Chapman & Hall, London; Reinhold, New York, 1955. 155 pp. $4.50.

**Stuttering in Children and Adults.** Thirty years of research at the University of Iowa. Wendell Johnson, Ed. Univ. of Minnesota Press, Minneapolis, 1955. 472 pp. $5.

**Principles of Meteorological Analysis.** Walter J. Saucier. Univ. of Chicago Press, Chicago, 1955. 438 pp. $10.

**Recent Progress in Hormone Research.** vol. XI. Proceedings of the 1954 Laurentian Hormone Conference. Gregory Pincus, Ed. Academic Press, New York, 1955. 518 pp. $10.

**The Convolution Transform.** I. I. Hirschman and D. V. Widder. Princeton Univ. Press, Princeton N.J., 1955. 268 pp. $5.50.

**Textbook of Anatomy and Physiology.** Diana Clifford Kimber and Carolyn E. Gray. Rev. by Caroline E. Stackpole and Lutie C. Leavell. Macmillan, New York, ed. 13, 1955. 850 pp. $5.

**'Sound Barrier'.** The story of high-speed flight. Neville Duke and Edward Lanchbery. Philosophical Library, New York, rev. ed., 1955. 129 pp. $4.75.

**Advances in Internal Medicine.** vol. VII. William Dock and I. Snapper. Year Book, Chicago, Ill., 1955. 311 pp. $8.50.

**Culture and Experience.** A. Irving Hallowell. Univ. of Pennsylvania Press, Philadelphia, 1955. 434 pp. $7.

**Discovering Buried Worlds.** André Parrot. Trans. by Edwin Hudson. Philosophical Library, New York, 1955. 127 pp. $3.75.

**Fifth Symposium (International) on Combustion.** Combustion in engines and combustion kinetics. Standing Committee on Combustion Symposia of the Combustion Institute. Reinhold, New York; Chapman & Hall, London, 1955. 802 pp. $15.

**Cardiolipin Antigens, Preparation and Chemical and Serological Control.** WHO Monogr. No. 6. Mary C. Pangborn, J. O. Almeida, F. Maltaner, A. M. Silverstein, and W. R. Thompson. World Health Organization, Geneva, ed. 2, 1955 (Distr. by Columbia Univ. Press, New York). 52 pp. Paper, $1.25.

**Perspectives and Horizons in Microbiology.** A symposium. Selman A. Waksman, Ed. Rutgers Univ. Press, New Brunswick, N.J. 1955. 220 pp. $3.50.

**The Principles of Electromagnetism.** E. B. Moullin. Oxford Univ. Press, Oxford, ed. 3, 1955. 438 pp. $8.

**Proceedings of the International Conference on Theoretical Physics.** Kyoto and Tokyo, September 1953. Science Council of Japan, Ueno Park, 1954. 945 pp. $10.

**The Mask of Sanity.** An attempt to clarify some issues about the so-called psychopathic personality. Hervey Cleckley. Mosby, St. Louis, ed. 3, 1955. 596 pp. $9.50.

**Trees and Shrubs of the Upper Midwest.** Carl Otto Rosendahl. Univ. of Minnesota Press, Minneapolis, rev. ed., 1955. 411 pp. $6.

**Modern Physics.** John C. Slater. McGraw-Hill, New York–London, 1955. 322 pp. $5.50.

**This World of Ours.** Abram Glaser. Philosophical Library, New York, 1955. xiii + 493 pp. $5.

**Quantitative Spectrochemical Analysis of Silicates.** A scheme of quantitative dc arc analysis of the silicate minerals, rocks, soils and meteorites. L. H. Ahrens. Pergamon Press, London; Addison-Wesley, Cambridge, Mass. 1955. 122 pp. $3.75.

**College and University Business Administration.** vol. 2. National Committee on the Preparation of a Manual on College and University Business Administration. American Council on Education, Washington, 1955. 267 pp. $4.50.

**Brazing Manual.** Committee on Brazing and Soldering, American Welding Soc. Reinhold, New York; Chapman & Hall, London, 1955. 193 pp. $4.75.

**Agricultural Regions of the United States.** Ladd Haystead and Gilbert C. Fite. Univ. of Oklahoma Press, Norman, 1955. 288 pp. $4.

**Elements of the Theory of Real Functions.** J. E. Littlewood. Dover, New York, rev. ed. 3, 1954. 71 pp. Paper, $1.35; cloth, $2.85.

**Handbook of Private Schools.** An annual descriptive survey of independent education. Porter Sargent, Boston, ed. 36, 1955. 1252 pp.

**Real Projective Plane.** H. S. M. Coxeter. Cambridge Univ. Press, ed. 2, 1955. 226 pp. $4.75.

**A Statistical Study of Livestock Production and Marketing.** Cowles Monogr. No. 15. Clifford Hildreth and F. G. Jarrett. Wiley, New York; Chapman & Hall, London, 1955. 156 pp. $4.50.

**Technical Supplement to the Bomb Survival and You.** Fred N. Severud and Kurt Bernhard. Reinhold, New York, 1955. 45 pp. $2.50.

**The Structural Relations of Natural Products.** Being the first Weizmann memorial lectures, December, 1953. Robert Robinson. Oxford Univ. Press, New York–London, 1955. 150 pp. $4.

**The Interpretation of Dreams.** Sigmund Freud. Trans. by James Strachey. Basic Books, New York, 1955. 692 pp. $7.50.

**F. Schuyler Mathews' Field Book of American Wild Flowers.** Rev. and enlarged by Norman Taylor. Putnam, New York, ed. 4, 1955. 601 pp. $5.

**Alcoholics Anonymous.** The story of how many thousands of men and women have recovered from alcoholism. Alcoholics Anonymous, New York, ed. 2, 1955. 575 pp. $4.50.

**Hydraulic Operation and Control of Machines.** Ian McNeil. Ronald, New York, 1955. 324 pp. $7.50.